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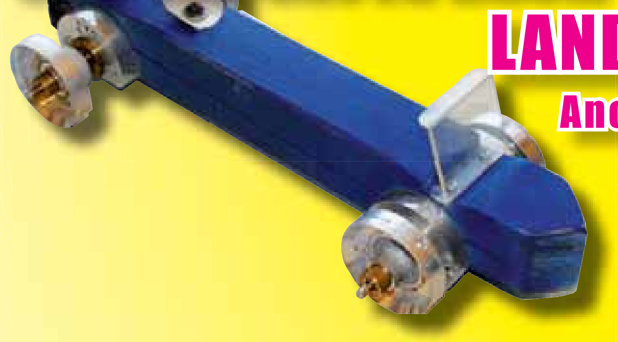

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MICROCHIP

ISSN 0262 3617
● PROJECTS ● THEORY ●
● NEWS ● COMMENT ●
● POPULAR FEATURES ●
VOL. 40. No 9 September 2011

EPE EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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Projects and Circuits

Series and Features

Regulars and Services

Our October 2011 issue will be published on Thursday 8 September 2011, see page 80 for details.

HOT Selling Kits for Electronic Enthusiasts

KIT OF THE MONTH

12/24VDC 20A Motor Speed Controller Kit
KC-5502 £14.50 plus postage & packing

Control the speed of 12 or 24VDC motors from zero to full power, up to 20A. Features optional soft start, adjustable pulse frequency to reduce motor noise, and low battery protection. The speed is set using the onboard trimpot, or by using an external potentiometer (available separately, use RP-3510 £0.98).

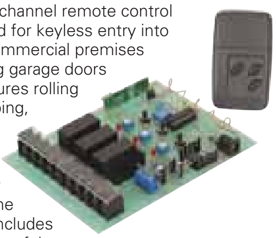
- Kit supplied with PCB and all onboard electronic components
- Suitable enclosure UB3 case, HB-6013 £1.50

NEW 2011

SECURITY KITS

UHF Rolling Code Remote Switch Kit
KC-5483 £36.25 plus postage & packing

High-security 3-channel remote control that can be used for keyless entry into residential or commercial premises or for controlling garage doors and lights. Features rolling code/code hopping, the access codes can't be intercepted and decoded by undesirables. The transmitter kit includes a three button key fob case and runs on a 12V remote control battery. The receiver is a short-form kit without case so you can mount it in the location or enclosure of your choice.



- Receiver 12VDC @ 150mA (1A for door strike use)
- PCB: Transmitter: 34 x 56mm
- Receiver: 110 x 141mm

Also available to suit:
Additional Transmitter Kit
KC-5484 £14.50

Don't just sit there BUILD SOMETHING!

Rolling Code Infrared Keyless Entry System
KC-5458 £23.75 plus postage & packing

This keyless entry system features two independent door strike outputs and will recognise up to 16 separate key fobs. The system keeps the coded key fobs synchronised to the receiver and compensates for random button presses while the fobs are out of range. Supplied with solder masked and silk screen printed PCB, two programmed micros, battery and all electronic components.

MORE INFO AVAILABLE ONLINE

- Receiver requires a 12VDC 1.5A power supply
- Some SMD soldering is required
- PCB: 61 x 122mm

Speedo Corrector MkII Kit

KC-5435 £20.00 plus postage & packing

When you modify your gearbox, diff ratio or change to a large circumference tyre, it may result in an inaccurate speedometer. This kit alters the speedometer signal up or down from 0% to 99% of the original signal. With this improved model, the input setup selection can be automatically selected and it also features an LED indicator to show when the input signal is being received. Kit supplied with PCB with overlay and all electronic components.

- PCB: 105 x 61mm
- Recommended box UB5 use HB-6013 £1.50

Universal Voltage Switch

KC-5377 £12.00 plus postage & packing

This is a universal module which can be adapted to suit a range of different applications. It will trip a relay when a preset voltage is reached. It can be configured to trip with a rising or falling voltage, so it is suitable for a wide variety of voltage outputting devices. For example throttle position sensor, air flow sensor, EGO sensor. You could even use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more. Kit supplied with PCB, and all electronic components.

- PCB: 105 x 60mm

Universal Power Supply Regulator

KC-5501 £5.50 plus postage & packing

This is an upgraded version of the original universal power supply kit published in August 1988. One small board and a handful of parts will allow you to create either a regulated ±15V rail or +15VDC single voltage from a single winding or centre tap transformer (not included). See website for more details.

- Includes all PCB and components for board, transformer not included
- PCB: 72(L) x 30(W)mm

NEW 2011

Ultrasonic Antifouling for Boats

KC-5498 £90.50 plus postage & packing

Marine growth electronic antifouling systems can cost thousands. This project uses the same ultrasonic waveforms and virtually identical ultrasonic transducers mounted in sturdy polyurethane housings. By building yourself (which includes some potting) you save a fortune! Standard unit consists of control electronic kit and case, ultrasonic transducer, potting and gluing components and housings. The single transducer design of this kit is suitable for boats up to 10m (32ft); boats longer than about 14m will need two transducers and drivers. Basically all parts supplied in the project kit including wiring. (Price includes epoxies).

Hundreds Sold!

- 12VDC
- Suitable for power or sail
- Could be powered by a solar panel/wind generator
- PCB: 78 x 104mm

"Minivox" Voice Operated Relay

KC-5172 £6.00 plus postage & packing

Voice operated relays are used for 'hands free' radio communications and some PA applications etc. Instead of pushing a button, this device is activated by the sound of a voice. This tiny kit fits in the tightest spaces and has almost no turn-on delay. 12VDC @ 35mA required. Kit is supplied with PCB electret mic, and all specified components.

- PCB: 47 x 44mm

An excellent way for new comers to dip their toes into the wonders of electronics!

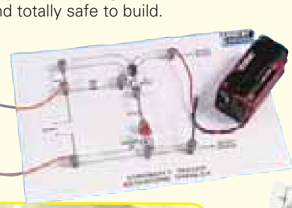
SHORT CIRCUITS - VOLUME 1

This volume will teach you everything you need to get started in electronics and is suitable for ages 8+. We give you the option of buying the book on its own, or together with the accompanying kit that contains the components for each of the 20-odd projects described in the book. Some of the exciting projects include a Police Siren, Electronic Organ, Sound Effects Unit, Light Chaser and many, many more! The full colour 96 page book, is lavishly illustrated with over 100 drawings and diagrams. No prior knowledge of electronics is needed, projects are fun and totally safe to build.

Short Circuits Book
BJ-8502 £3.75

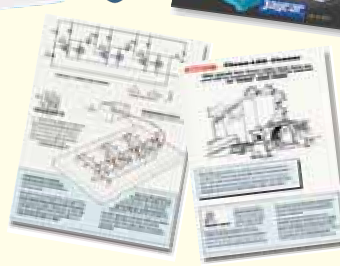
Short Circuits Project Kit
KJ-8504 £12.50

Short Circuits Book and Project Kit
KJ-8502 £14.85



MORE INFO AVAILABLE ONLINE

AGES 8+



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£200 - £499.99	£30
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Digital Record/Player
Non volatile flash memory, Single 20 sec recording via integral mic, 2W output to 8Ω speaker.
Power: 5Vdc 100mA
C-9701 Cebek Module £7.89
3rd Brake Light Flasher Kit
Works with any incandescent or LED rear centre brake light. Flashes at 7Hz for 5 or 10 times, adjustable re-triggering.
Power: 12Vdc max load 4A
MK178 Velleman kit £6.30
Multifunction Up/Down Counter
An up or down counter via on-board button or ext input. Time display feature. Alarm count output. 0-9999 display.
Power: 9-12Vdc 150mA
K8035 Velleman kit £17.85
2 Digital Counter
Standard counter, 0 to 99 from input pulses or external signal. With reset input, 13.5mm Displays,
Power: 12Vdc 90mA.
CD-9 Cebek Module £12.99
Digital Clock Mini Kit
Red 7 Segment display in attractive enclosure, automatic time base selection, battery back-up, 12 or 24Hr modes.
Power: 9Vac or dc
MK151 Velleman kit £15.09
Nixie Clock Kit
Gas filled nixie tubes with their distinctive orange glow. HH:MM display, automatic power sync 50/60Hz
Power: 9-12Vac 300mA
K8099 Velleman kit £64.96
1.8W Mono Amplifier
Compact mono 1.8W RMS 4Ω power stage, short circuit & reverse polarity protection. 30-18kHz, Power: 4-14Vdc 150mA
E-1 Cebek Module £5.87
Proximity Card Reader Kit
A simple security kit with many applications. RFID technology activates a relay, either on/off or timed. Supplied with 2 cards, can be used with up to 25 cards. Power: 9Vac or dc
MK179 Velleman kit £14.25
Mini USB Interface Board
New from Velleman this little interface module with 15 inputs/outputs inc digital & analogue in, PWM outputs. USB Powered 50mA, Software supplied
VM167 Module £26.80
20W 2 Channel Amplifier
Mono amplifier with 2 channels (Low & High frequecy), 20W RMS 4Ω per channel, adjustable high level. 22-22kHz, short circuit & reverse polarity protection.
Power: 8-18Vdc 2A
E-14 Cebek Module £22.11
Running Microbug Kit
Powered by two subminiature motors, this robot will run towards any light source. Novel shape PCB with LED eyes.
Power: 2 x AAA Batteries
MK127 Velleman kit £9.02
Thermostat Mini Kit
General purpose low cost thermostat kit. +5 to +30°C Easily modified temperature range/min/max/hysteresis 3A Relay
Power: 12Vdc 100mA
MK138 Velleman Kit £4.55
5W Stereo Amplifier
Stereo power stage with 5W RMS 4Ω, 30-18kHz, short circuit & reverse polarity protection.
Power: 6-15Vdc 500mA
ES-2 Cebek Module £21.54
200W Power Amplifier
A high quality audio power amp, 200w music power @ 4Ω 3-200kHz Available as a kit without heatsink or module including heatsink.
K8060 Velleman kit £12.85
Heatsink for kit £9.95
VM100 Module £38.54
Velleman Function Generator
PC Based USB controlled function generator. 0.01Hz to 2Mhz Pre-defined & waveform editor. Software supplied. See web site for full feature list.
PCGU1000 Velleman £118.38
12Vdc Power Supply
Single rail regulated power supply complete with transformer. 130mA max, low ripple, 12Vdc with adjustment.
FE-103 Cebek Module £13.16
MP3 Player Kit
Plays MP3 files from an SD card, supports ID3 tag which can be displayed on optional LCD. Line & headphone output. Remote control add-on. Power: 12Vdc 100mA
K8095 Velleman kit £39.99
Velleman PC Scope
PC Based USB controlled 2 channel 60Mhz oscilloscope with spectrum analyser & Transient recorder. 2 Scope probes & software included. See web site for full feature list.
PCSU1000 Velleman £249.00
1-180 Second Timer
Universal timer with relay output. Time start upon power up or push button. LED indication. 5A Relay
Power: 12Vdc 60mA
I-1 Cebek Module £12.92
DC to Pulse width Modulator
A handy kit to accurately control DC motors etc. Overload & short circuit protection. Input voltage 2.5-35Vdc, Max output 6.5A.
Power: 8-35Vdc
K8004 Velleman kit £9.95
Velleman PC Scope/Generator
PC Based USB controlled 2 channel oscilloscope AND Function generator. Software included. See web site for full feature list.
PCSGU250 Velleman £113.67
Cyclic Timer
Universal timer with relay output. Time start upon power up or push button. On & Off times 0.3-60 Seconds, LED indication. 5A Relay
Power: 12Vdc 80mA
I-10 Cebek Module £14.12
Audio Analyser Kit
A small spectrum analyser with LCD. Suitable for use on 2, 4 or 8Ω systems. 300mW to 1200W(2Ω) 20-20kHz Panel mounting, back-lit display. Power: 12Vdc 75mA
K8098 Velleman kit £31.65
RF Remote Control Transmitter
Single channel RF keyfob transmitter with over 13,122 combinations. Certified radio frequency 433.92MHz.
Power: 12Vdc 2mA (inc) For use with TL-1,2,3,4 receivers.
TL-5 Cebek Module £14.64
Light Detector
Adjustable light sensor operating a relay. Remote sensor & terminals for remote adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-4 Cebek Module £13.98
USB DMX Interface
512 DMX Channels controlled by PC via USB. Software & case included. Available as a kit or ready assembled module.
K8062 Velleman kit £47.90
VM116 Module £67.15
RF Remote Control Receiver
Single channel RF receiver with relay output. Auto or manual code setup. Momentary output, 3A relay
Power: 12Vdc 60mA For use with TL-5 or TL-6 transmitters.
TL-1 Cebek Module £28.25
Liquid Level Detector
A liquid level operated relay. Remote sensor operates relay when in contact with a liquid. 5A Relay
Power: 12Vdc 60mA
I-6 Cebek Module £13.08
USB Interface Board
Featuring 5 in, 8 digital outputs, 2 in & 2 analogue outputs. Supplied with software. Available as a kit or ready assembled module.
K8055 Velleman kit £24.80
VM110 Module £34.90
Keypad Access Control
An electronic lock with up to ten 4 digit codes. Momentary or timed (1-60ec/1-60min) output. Relay 5A
Power: 12Vdc 100mA Keypad included.
DA-03 Cebek Module £54.26
Thermostat
A temerature controlled relay. Adjustable between -10 to 60°C Sensor on remote PCB. Connector for external adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-8 Cebek Module £12.80
8 Channel USB Relay Board
PC Controlled 16A relays with toggle, momentary or timed action. Test buttons included, available in a kit or assembled.
K8090 Velleman kit £39.95
VM8090 Module £58.40
AC Motor Controller
A 230Vac 375W motor speed control unit giving 33 to 98% of full power.
Power: 230Vac
R-8 Cebek Module £12.14
Start / Stop Relay
Simple push button control of a relay. Either 1 or 2 button operation 5A Relay
Power: 12Vdc 60mA
I-9 Cebek Module £12.83
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PROJECTS AND CIRCUITS
All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

COMPONENT SUPPLIES
We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.
We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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Ingenuity Unlimited – Pico prize winners

One of the nicest perks of being editor of *EPE* is reading the many designs that readers dream up and send in for *Ingenuity Unlimited*. Every 20 or so published entries, *EPE* awards a couple of very desirable prizes. The lucky winners receive superb PC-based Oscilloscopes, generously donated by Pico Technology, to whom we again extend our thanks and appreciation for sponsoring the column. For more information about Pico's range of test equipment, visit their website at **www.picotech.com**, or see their advertisement on page 45 of this issue.

EPE publisher and former editor Mike Kenward and I considered a wonderfully varied collection of published *Ingenuity Unlimited* entries, and after much deliberation, we have decided that the prize winners are: as follows.

Winner – receives a superb PicoScope 3206 Digital Storage Oscilloscope worth £799: Murray Ward – *Regulating Grandfather By Radio* (February 2010). This project really displayed the kind of 'ingenuity' that gives the column its name. Murray combined a radio time signal, a cheap radio clock, analogue electronics and electromechanical components to regulate the pendulum of his 18th century grandfather clock (without altering the clock's precious 'works'). Murray is a worthy winner, well done.

Runner up – a PicoScope 2105 Handheld 'Scope worth £199: Ivan Eamus – *PCB Track Probing Unit* (July 2011). An excellent circuit design for tracing printed circuit tracks between components, IC pins, and sockets, even if components populate the PCB, but without power being connected. This is a genuinely useful bit of kit for project assemblers.

Choosing winners is never easy, especially with the design quality, originality and usefulness of many of the entries. So, while the following didn't make it to winner status, we wish to give them 'honourable mentions for displaying great ingenuity':

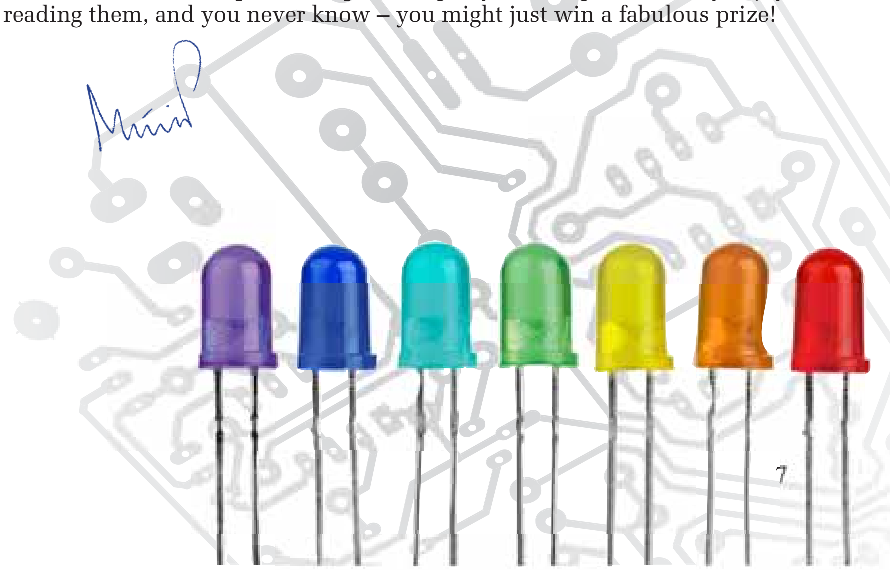
Nick Dossis – *Universal Remote Control Receiver* (April 2011) – for finding a handy use for discarded IR 'remotes'.

Thomas Scarborough – *Seeing Eye* (November 2010) – designing a very sensitive detector of light level changes.

M Forbes – *Tuner Control* (January 2009) – a nice design for where a voltage controlled function is required with good resolution and noiseless operation.

Walter Gray – *Simplified Stroboscope* (October 2009) – a useful project that uses high-intensity LEDs instead of a traditional gas discharge lamp.

Last, but not least, do please keep sending in your designs, we really enjoy reading them, and you never know – you might just win a fabulous prize!



NEWS

A roundup of the latest Everyday News from the world of electronics

Be sure of your facts by Barry Fox

Company bosses traditionally give keynote speeches at industry conferences to enhance their standing. But sometimes the policy can backfire – which it did at the recent annual consumer electronics conference hosted by Intellect, the UK trade association for the technology industry.

Sony dismisses hacking as an 'incident'

Gildas Pelliet, new managing director at Sony UK, presented the keynote speech with his view of the new 'connected world'. But he surprised the audience by referring to the recent disastrous hacking of Sony's Playstation network, in which over 100 million accounts were comprised, only as an 'incident' and hoping the network was 'now robust'.

Pelliet then strongly urged the UK's Digital TV Group to talk again to the European Hybrid Broadcast Broadband TV or 'HbbTV' consortium about the standard for Connected TV, but failed to explain why. He said he was 'disappointed' by the UK's broadband service, but pleased that the UK government had committed to 2Mbps broadband for everyone by 2013. He also referred to Blu-ray starting in 2000, when in fact the format launched in 2006.

At the end of his speech, Pelliet was visibly shocked to be 'corrected' by conference moderator Rory Cellan-Jones, BBC Technology Correspondent, who said firmly: 'I am sorry to tell you your slide was wrong, because the government has now changed the broadband for all date to 2015'.

Then asked by Cellan-Jones to explain what he thought the DTG was doing wrong over Connected TV and HbbTV, Pelliet had to admit he 'didn't know enough about the subject'.

When asked by Cellan-Jones about the PSN hacking 'incident', which 'destroyed trust in Sony', Pelliet insisted Sony had 'reacted with high speed' and 'the good news is no one has been a victim of fraud'.

Finally, when asked from the floor to elaborate on his reference to the new Ultraviolet standard for downloading music, movies and books to a personal Digital Locker, Pelliet admitted he was 'not familiar with it.'

Wired by a five-year old? Too many cable companies claim great technology credentials but seem incapable of even basic installation tasks, blighting the British urban landscape with this kind of mess. Photo: Barry Fox

A North London street earlier this year; 'bombproof' might be excessive, but a cabinet that uses mains power (see fuse and meter lower right) and houses delicate and important equipment ought to be good enough to keep its doors shut. A design that can't is simply not fit for purpose. Photo: Barry Fox

Virgin media cabinets

At the same conference, Neil Berkett, Virgin Media CEO, gave a separate keynote speech on 'The changing relationship between content and platforms' 'The Killer App for broadband is bandwidth', said Berkett. 'Virgin is a trusted brand. Our fibre optic network passes over half of UK homes. We have invested in next generation infrastructure to build a Digital Britain'

But Berkett was also visibly shocked when reminded that anyone waking the streets in a Virgin area will see two kinds of telecoms street furniture – bombproof steel boxes installed by BT, and flimsy cabinets owned by Virgin and often open to rain and snow with the electronics and wiring exposed to the elements and hackers. Even worse situations can be seen on the roofs of blocks of flats.

'I have never had that question before' admitted Berkett, obviously taken off guard. 'Open cabinets can cause higher fault rates. We do need to address leakage, which can affect upload speeds. But I can't do anything about our predecessors' 550,000 boxes. I am not going to spend money on making them bombproof.'

IET introduces updated wiring standard

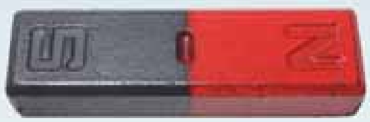
The Institution of Engineering and Technology (IET, formerly the IEE) has launched *The IET Wiring Regulations, 17th Edition, BS 7671:2008* incorporating Amendment No.1, 2011. The amended *IET Wiring Regulations* set out the national standard for which all new electrical installations are to comply.

The amended *Wiring Regulations* have been jointly published by the IET and the British Standards Institution (BSI) and feature important changes to the 17th Edition, which was published in 2008.

The amended *IET Wiring Regulations* can be purchased from **www.theiet.org/amend1**. You can find out more about the new requirements for electrical installations, or speak to an expert at the IET on: 01438 765599 or email: **technical@theiet.org**

North-south, or 1-0?

According to a report from Berkeley University in California, future computers may rely on magnetic microprocessors that consume the least amount of energy allowed by the laws of physics.



Today's silicon-based microprocessor chips rely on electric currents, or moving electrons, that generate a lot of waste heat. But microprocessors employing nanometre-sized bar magnets – like tiny refrigerator magnets – for memory, logic and switching operations theoretically would require no moving electrons.

Such chips would dissipate only 18 millielectronvolts of energy per operation at room temperature, the minimum allowed by the second law of thermodynamics and called the Landauer limit. That's one million times less energy per operation than consumed by today's computers.

Armchair miracle

While much of the debate around electrical power focuses on choosing the best sources, from coal, nuclear or renewable supplies, other important areas are now the focus of research, in particular looking to crack down on the power lost in transmission lines, however it is generated. Scientists from Rice University in Texas have achieved an important breakthrough in the development of a cable that may make possible a much more efficient electric grid of the future.

Nanotube researchers are aiming to revolutionise the transmission of power

A prime technical hurdle in the development of this 'miracle cable', or armchair quantum wire (AQW), is the manufacture of massive amounts of metallic single-walled carbon nanotubes, which are dubbed 'armchairs' for their unique shape, said Rice chemist Andrew Barron.

The AQW will be a weave of metallic nanotubes that can carry electricity with negligible loss over long distances. It will be an ideal replacement for a nation's copper-based grid, which leaks electricity at an estimated 5% per 100 miles of transmission, said Barron, author of a paper about the latest step forward, published online by the American Chemical Society journal *Nano Letters*.

Armchairs are best for carrying current, but can't yet be made alone. They grow in batches with other kinds of nanotubes and have to be separated out, which is a difficult process, given that a human hair is 50,000 times larger than a single nanotube.

Barron's lab demonstrated a way to take small batches of individual nanotubes and make them dramatically longer. Ideally, long armchair nanotubes could be cut, re-seeded with catalyst and regrown indefinitely.

Amplification of nanotubes was seen as a key step toward the practical manufacture of AQW by the late Rice professor, nanotechnology pioneer and Nobel laureate Richard Smalley.

The key was finding the right balance of temperatures, pressures, and reaction times to promote growth, Barron said.

Parallax GPS receiver module

Parallax have launched a new GPS receiver module. The VPN1513 provides a fully open source and customisable GPS receiver solution for microcontroller projects. It uses a SiRF Star III chipset capable of tracking up to 20 satellites. The module supports both 'raw' output mode for NMEA 0183 strings and the default 'smart' mode for specific user-selected data via a serial interface.

The VPN1513 also features a Propeller coprocessor for easy interface with any BASIC Stamp 2 module. The Propeller is also fully reprogrammable and includes access to all 32 IO pins, allowing the GPS receiver module to be easily transformed into a standalone device.

Microchip brings advanced control to cost-sensitive designs with new devices

Microchip has announced a new series of 16-bit PIC microcontrollers (MCUs) and dsPIC digital signal controllers (DSCs) that bring advanced control to cost-sensitive general purpose and motor-control designs. The new devices enable low-cost, sensor-less motor control designs, with support for a wide range of motor-control algorithms, plus an on-chip charge time measurement unit (CTMU), 10-bit analogue-to-digital converter (ADC) and mTouch capacitive touch sensing to enable intelligent sensor applications.

The devices are supported by three new plug-in modules and a single-board motor control starter kit that includes capacitive-touch sliders and an onboard brushless DC motor. This makes it easy for designers to create high-performance personal projects or appliances, such as washing machines, medical products such as infusion pumps, and industrial AC-induction motors, as well as other cost-sensitive applications.

For more information, visit Microchip's website at: **www.microchip.com/get/PFG6**. A video demo of the kit can be viewed on YouTube at: **www.microchip.com/get/RUBM**

Are you listening to CDs via your DVD player? Does your DVD player have average sound quality or worse, cause buzz and hum problems when hooked up to your hifi system? Either way, you need this high-quality Stereo Digital-To-Analogue Converter (DAC) to get first class sound and zero hum.

THIS 24-BIT, 96kHz-capable stereo DAC provides sound quality equal to the best high-end CD players, regardless of price. It has one coaxial S/PDIF input and two TOSLINK (optical) inputs, to which you can connect a DVD player, set-top box, DVR, computer or any other source of linear PCM digital audio. It also has left and right RCA phono sockets for connection to a stereo amplifier or home theatre receiver.

If you already own a DVD player of average quality or better, you can hook it up to this DAC and immediately upgrade the sound quality.

Unfortunately, most DVD players have mediocre audio quality from their audio outputs, especially in terms of distortion. So why are typical DVD players so poor in audio performance? Partly, it is because they are designed down to a very low price, and while their on-board DAC might be quite a reasonable component, the supporting circuitry has been cut to the bone in order to keep the overall price as low as possible. It is also true that many cheap (and not so cheap) DVD players are plagued with quite strong extraneous RF in the audio outputs, mainly related to the video output signals that they continuously produce, regardless of whether they are playing DVDs or CDs.

In addition, virtually all DVD players, except the most expensive models, use switch-mode power supplies. These have the advantage of being very efficient and especially with respect to recent models, have very low standby power consumption. The drawback of switch-mode power supplies is that

Build a high-quality stereo DAC for superb sound from your DVD player

Part 1: Design by NICHOLAS VINEN

oth optical and coaxial inputs

they produce lots of switching harmonics, which can work their way into the audio outputs.

Finally, because all DVD players these days are double-insulated and come with two-core power cords, they inevitably cause hum and buzz when connected to the audio inputs of high-fidelity amplifiers, which are usually earthed via a three-core mains cord. There is no simple way to fix any of these problems, but this new DAC project fixes them all and provides first-class audio performance into the bargain.

Main features

Our prototype DAC is housed in a one-unit high rack-mount case. The front-panel controls are just an on/off switch and three LED-illuminated momentary pushbuttons.

In operation, the DAC scans for a valid signal on one of its three digital inputs, and when one is detected, it immediately locks onto it and works. Alternatively, you can select the wanted input signal by pressing the relevant button, or you can do it with a Philips RC5-compatible remote control (such as most universal remotes) which can also be used to control the volume from the left and right outputs.

As previously stated, the unit accepts both TOSLINK (optical) and coaxial (S/PDIF) inputs, while a pair of RCA phono sockets is used for the left and right stereo outputs.

User interface

The user interface provides two functions – display of the DAC status and control over its configuration, primarily selecting between inputs.

Status display is provided by the five LEDs on the front panel. The LEDs in the three illuminated pushbuttons show which of the three channels is currently selected. They correspond, left-to-right, to the inputs on the rear panel – the RCA S/PDIF input is number 3.

The two other LEDs indicate whether there is a valid S/PDIF signal detected on that channel (yellow LED) and whether any audio data is present (green LED). The yellow LED also flashes to acknowledge signals from the remote control.

Holding down various combinations of the buttons on the front panel allows you to enter a set-up mode where you can assign remote control functions and configure the automatic input switching.

The automatic input switching system allows the DAC to select whichever input has a valid signal. It allows you to leave the DAC on and switch between various input sources, without the need to manually change channels.

Specifications

Signal-to-noise ratio:	–108dB (unweighted, 22Hz to 22kHz) –114dB (A-weighed), both with respect to 2V RMS
Total harmonic distortion:	<0.0018% @ 1kHz and 2V RMS
Channel separation:	–105dB @ 100Hz and 1kHz –85dB @10kHz –73dB @ 20kHz
Linearity:	within 1dB @ –90dB
Frequency response:	+0.0, –0.15dB, 20Hz to 20kHz
Supported sample rates:	28 to 108kHz
Supported bit depths:	16-bit, 20-bit and 24-bit
Supported channel formats:	stereo PCM
Clock Jitter:	jitter tolerant; clock jitter is typically < 50ps

For example, if you have a DVD player and set-top box connected, and after watching a DVD you switch the DVD player off and the set-top box on, the DAC will change inputs by itself about 10 seconds after you've turned the DVD player off. This delay can be changed, depending on your preference.

How it works

In operation, the DAC constantly monitors the current input status for two parameters: (1) the presence of an S/PDIF signal, and (2) the presence of audio data (non-silence). This is the same information which is displayed via the status LEDs. After a user-defined period (default 10 seconds) without a valid signal, the input channels will enter a 'scanning' mode, where each input is rapidly selected in turn. This scanning continues until a valid signal is detected, at which point it stops on that input.

There is also a user-defined period of silence (default one minute) after which scanning will begin, even with a valid signal present. This is because many devices with digital audio outputs keep their outputs active, even when they are not playing any material; for example, when the DVD is stopped. Thus, the only reliable way to determine if content is actually being played is to look for an audio signal.

Of course, you don't want it to start scanning the instant there is silence, as there are often short silent periods between tracks, or you may be changing discs or briefly pausing playback.

The two delays can be configured from 100ms up to several hours, or disabled entirely. In addition, it's possible to configure different delays if the current channel has been manually selected, either from the front panel buttons or the remote control. This is so that you can set the automatic scan times fairly short without having it start scanning too soon after you force it to a particular channel.

By default, these delays are set to five minutes without a signal and scan on silence after a manual channel change is disabled.

Default input and volume control

There is also the matter of which input is active when power is first applied. By default, the first input is selected, but you can configure it so that the default is any of the three inputs, or so that it immediately scans, or even so that it starts up with whichever input last had a valid signal before it was powered off.

Finally, there is a built-in volume control in the DAC, and it is possible to use the remote control to change the volume. This has a 30dB range, but we don't recommend using it if you want the very best sound quality. Because the volume control is digital, total harmonic distortion will become worse as the volume is reduced.

If you do control the volume using a remote, it will remember the last setting the next time it is powered on. The initial default is maximum volume and that's where it should be left for best sound quality.

Note also that multi-channel audio formats like DTS or Dolby Digital are not supported, and in any case, many DVD players turn off the TOSLINK (optical) output when multi-channel modes are employed. This means you have two choices when using this DAC with a DVD player in a home-theatre configuration. One option is to connect the DVD player's outputs directly to your amplifier, along with the DAC outputs, using a separate set of cables and switch between them, depending on whether you are playing multi-channel or stereo content.

Alternatively, if you only have stereo speakers, you can configure your DVD player to convert multi-channel content to stereo on the digital output and play all content via the DAC. Some, but not all, DVD players have such a feature, which is usually configured via an on-screen menu. If you just want to use a DVD player to play CDs you can ignore the DVD player's stereo outputs altogether, and just use the digital output. It is also possible to use a CD player with digital outputs, although they are becoming less common.

Because the DAC supports 24-bit 96kHz content, as well as CD quality (16-bit, 44.1kHz) and other common audio formats, it is also possible to play higher definition audio content. The supported range of sample rates is 28-108kHz, and recognised bit depths are 16, 20 and 24 bits (although in reality 16-bit content is always promoted to 20 bits when sent via S/PDIF). This covers most common linear audio formats. De-emphasis is also supported, although very few CDs are recorded with it enabled. However, de-emphasis has been included, since it is part of the CD Audio 'Red Book' standard.

While the ability to play back 24-bit 96kHz content is attractive, there is a catch: many devices capable of playing back audio of this quality disable their digital outputs when doing so! This often includes all 'DVD Audio' players, which is a great pity. Presumably, the music industry was worried about people making digital copies of such content and thus deny us the ability to use the digital output for high-quality content at all. No wonder DVD Audio failed to take off! However, even plain old CDs will sound great played back through this DAC, as long as they were properly recorded and mastered.

Clock jitter

Regarding the audio quality, not only does the DAC chip itself provide high-quality audio output, but also the

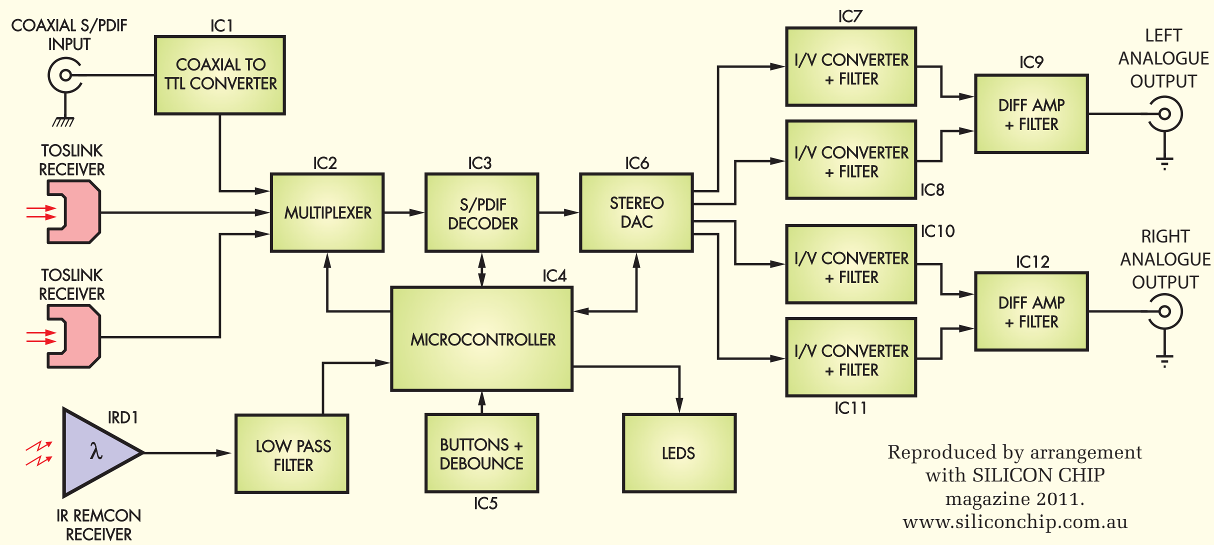


Fig.1: block diagram of the Stereo DAC. It has two TOSLINK (optical) inputs and one coaxial input and these are fed to an S/PDIF decoder (IC3) via a multiplexer (IC2) and then to a stereo DAC (IC6). The DAC then drives current-to-voltage converter stages IC7, IC8, IC10 and IC11, and finally the differential amplifier output stages (IC9 and IC12). The circuit is controlled by microcontroller IC4, which selects the input signal and accepts inputs from the IR remote control receiver and the pushbutton switches

S/PDIF decoder 're-clocks' the audio data to remove 'clock jitter'. Clock jitter refers to the fact that the clock frequency of the data being transmitted over the digital link varies somewhat from sample to sample. Ideally, there will be no jitter, meaning the clock pulses (and thus data bits) come at exactly the same interval, but consumer equipment often doesn't have the best clock stability, and this can prejudice the dynamic range.

The decoder solves this by re-clocking the data using a 'phase-locked loop' (PLL). The PLL's frequency is locked to the sample frequency of the data being received, but because only the average clock frequency determines the PLL frequency, if the PLL is sufficiently stable it will reject most of the jitter. The DIR9001 decoder from Texas Instruments/Burr Brown claims a typical specification of around 45 picoseconds (ps) jitter at 44.1kHz, and 30ps jitter at 96kHz when the master clock is running at 512f_S, which is how it is configured.

You may be wondering why the decoder IC chosen isn't capable of handling sample rates up to 192kHz. After all, the DSD1796 DAC supports this sample rate and some content is available at 192kHz, so it would be nice to support it.

The main reason is that Burr Brown does not make a 192kHz S/PDIF decoder, and other choices such as the Crystal CS8416 have inferior specifications, including jitter tolerance. For the CS8416, the output jitter is quoted as around 100ps – twice that of the DIR9001. Since most content available is still 44.1kHz or 48kHz, and since the difference in quality between 96kHz and 192kHz audio is minimal, we feel that the DIR9001 is the superior device.

PC board line-up

Inside the chassis, the circuitry is accommodated on four PC boards: an Input and Control Board, a Front-Panel Switch Board, a Stereo DAC/Analogue Board and a Power Supply Board. In the block diagram of Fig.1, the Stereo DAC and all blocks to its right are mounted on the DAC/Analogue Board, while the circuitry to the left is on the control board. The front panel board carries the buttons, LEDs and an infrared remote control receiver.

Not shown on Fig.1 is the power supply board. This is available from Jaycar (Cat. KC-5418) as a kit. It can be run from a small 15V-0V-15V toroidal transformer, or from a 15V AC plugpack.

Block diagram

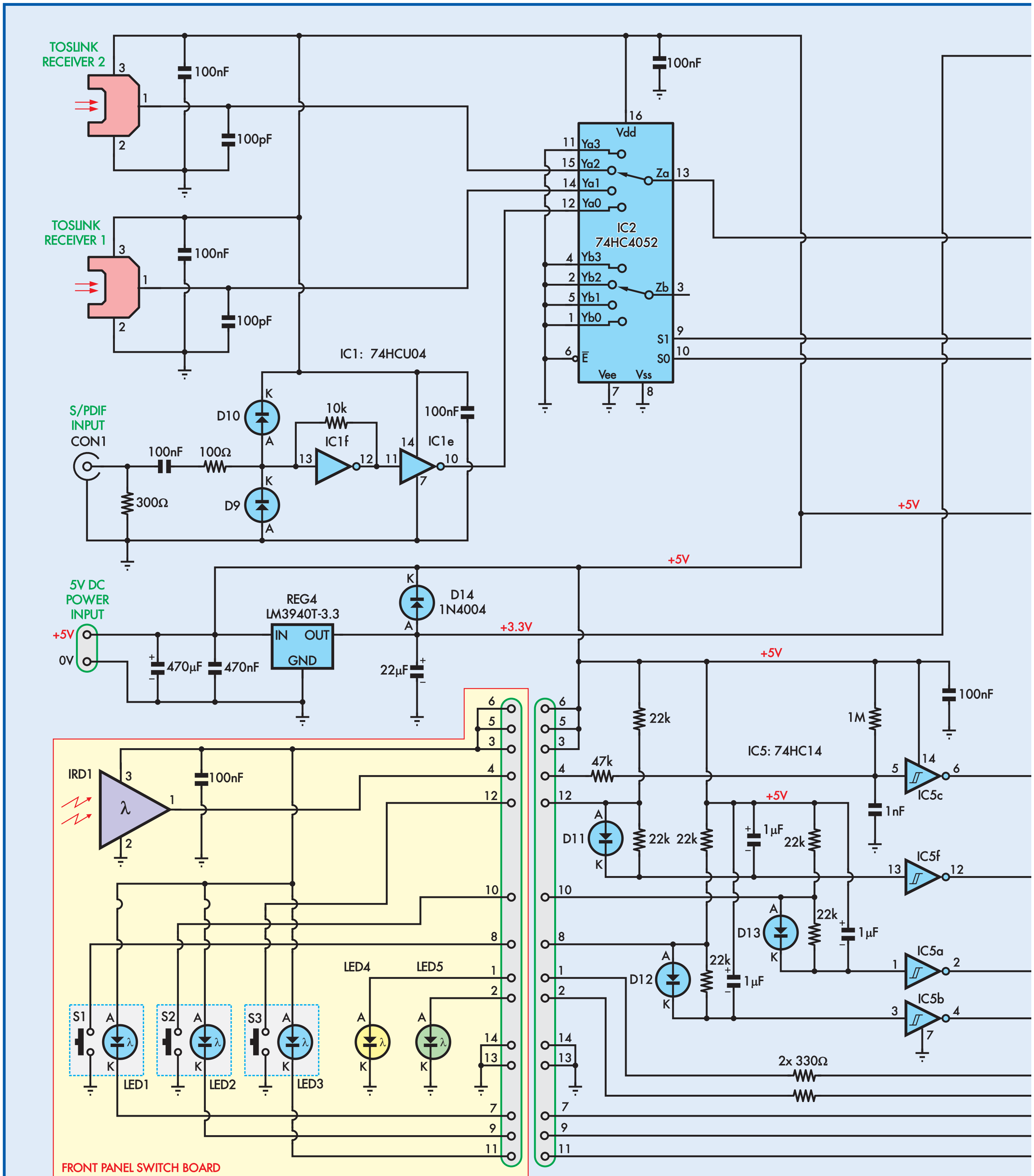
Fig.1 shows the main circuit sections. To the left are the two TOSLINK inputs, the S/PDIF input and the infrared (IR) remote control receiver. These are fed into multiplexer IC2, and then to the S/PDIF decoder IC3. The output of the decoder in turn feeds the stereo DAC (IC6), while all three are under the control of the microcontroller (IC4). IC4 also accepts inputs from the illuminated pushbutton switches and from the IR remote receiver (after filtering) and it drives the LEDs.

The DAC has two sets of differential outputs, and these drive four current-to-voltage converter stages involving IC7, IC8, IC10 and IC11. The four balanced voltage outputs from these stages then drive differential op amps IC9 and IC12 to derive the left and right audio outputs, respectively.

Circuit details

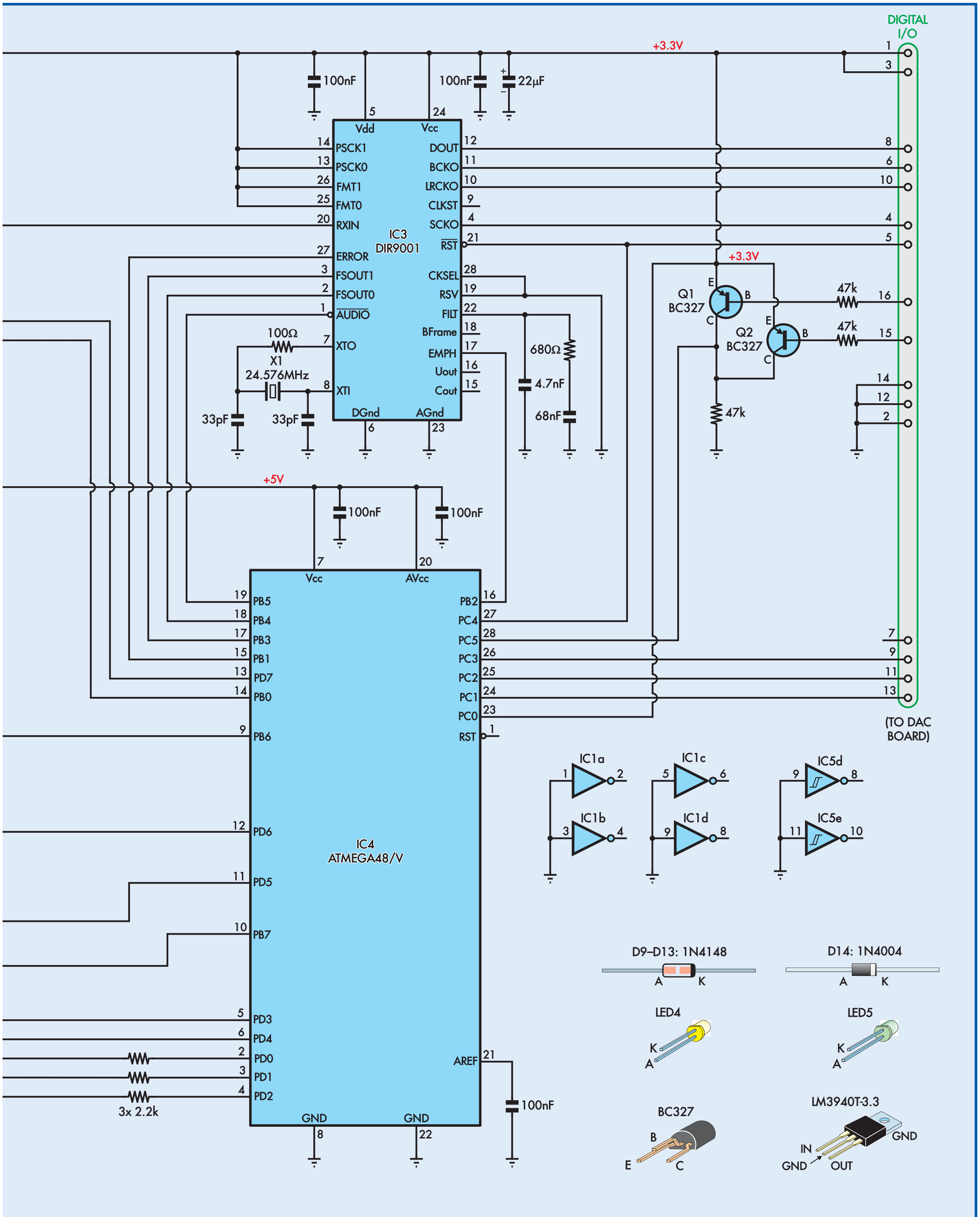
Now let's have a detailed look at the circuitry of the Input and Control Board – see Fig.2. The two TOSLINK optical receivers each deliver a TTL (5V peak) output signal. The coaxial input is a little more tricky because S/PDIF over coaxial cable (75Ω) is a fairly low level signal – around 0.5V peak-to-peak and even less after cable termination. Therefore, the coaxial signal receiver circuit consists of an amplifier which boosts this signal to TTL levels.

The resulting three TTL S/PDIF signals, one from each input, are then



STEREO DIGITAL-TO-ANALOGUE CONVERTER INPUT AND FRONT PANEL BOARDS

Fig.2: the Input Board carries the TOSLINK and S/PDIF inputs, the multiplexer (IC2), the S/PDIF decoder (IC3) and the microcontroller (IC4). The Front Panel Switch Board (yellow background) carries the switches, LEDs and IR receiver


DIGITAL I/O
+3.3V
100nF
100nF
22µF
Vdd
Vcc
PSCK1
PSCK0
FMT1
FMT0
RXIN
ERROR
FSOUT1
FSOUT0
AUDIO
XTO
XTI
DGnd
AGnd
DOUT
BCKO
LRCKO
CLKST
SCKO
RST
CKSEL
RSV
FILT
BFrame
EMPH
Uout
Cout
IC3
DIR9001
100Ω
X1
24.576MHz
33pF
33pF
680Ω
4.7nF
68nF
Q1
BC327
Q2
BC327
47k
47k
47k
+5V
100nF
100nF
Vcc
AVcc
PB5
PB4
PB3
PB1
PD7
PB0
PB6
PD6
PD5
PB7
PD3
PD4
PD0
PD1
PD2
PB2
PC4
PC5
PC3
PC2
PC1
PC0
RST
AREF
GND
GND
IC4
ATMEGA48/V
3x 2.2k
100nF
(TO DAC BOARD)
IC1a
IC1b
IC1c
IC1d
IC5d
IC5e
D9–D13: 1N4148
D14: 1N4004
LED4
LED5
BC327
LM3940T-3.3
IN
GND
OUT
GND

What are S/PDIF and TOSLINK?

The acronym S/PDIF (or SPDIF) stands for 'Sony/Philips Digital Interface'. Basically, it is a standardised serial interface for transferring digital audio data between consumer-level equipment such as DVD and CD players, DAT and DVD recorders, surround-sound decoders and home-theatre amplifiers.

S/PDIF is very similar to the AES3 serial digital interface used in professional recording and broadcasting environments. In operation, each digital audio sample (16-24 bits) is packaged along with status, control and error-checking information into a 32-bit binary word. This is then modulated or encoded into a serial bitstream using the biphase mark code (BMC).

BMC involves combining the data bits with a clock signal of twice the data bit rate, in such a way that a binary '1' results in two polarity reversals in one bit period, while a binary '0' results in a single polarity reversal. This double bit-rate signal is self-clocking at the receiving end and has no DC component.

The BMC encoded serial bitstream is then transmitted as a 400mV peak-to-peak signal along a single 75-ohm coaxial cable. In most cases, the cable connectors used are standard RCA phono or 'Cinch' connectors, as also used for analogue audio and composite video.

Although originally developed for conveying linear PCM (LPCM) digital audio signals, as used in CD and DAT audio, S/PDIF has also been adapted for conveying compressed digital audio, including Dolby Digital (AC-3), DTS and MPEG-2 audio.

TOSLINK is essentially just the S/PDIF signal format converted into the optical domain, for transfer along optical-fibre cables. The accompanying table (above) shows the most common domestic audio bitstream formats and the S/PDIF/TOSLINK bit rates for each one. Note that LPCM audio is rarely used for DVD-Video, because even a stereo audio track requires a BMC bit rate of 6.1Mb/s.

Many current-model DVD players and recorders are provided with either coaxial S/PDIF or TOSLINK digital audio inputs and outputs, or quite often a mixture of both. Similarly, many home-theatre amplifiers are provided with coaxial S/PDIF and/ or TOSLINK inputs. This is also the case with many up-market PC sound cards.

Digital Audio Bitstream Formats

SOURCE & CODING	CD-Audio (LPCM)	DVD-Video & DAT (LPCM)	DVD-Video (COMPRESSED)		
			DOLBY DIGITAL (AC-3)	MPEG-2 AUDIO	DTS AUDIO
SAMPLING RATE	44.1kS/s	48kS/s	48kS/s	48kS/s	48kS/s
MAX DATA BIT RATE	2822kb/s	3072kb/s	448kb/s	456kb/s	754.5kb/s
SPDIF (TOSlink) BMC BIT RATE	5644kb/s	6144kb/s	896kb/s	912kb/s	1509kb/s

fed into the 74HC4052 analogue/digital multiplexer (IC2). Just think of IC2 as a selector switch under the control of the microcontroller (IC4).

Depending on which input is selected by the microcontroller, one of them is fed into the DIR9001 Digital Audio Interface Receiver (IC3). This does the S/PDIF decoding. The DIR9001 requires a 3.3V supply, which is provided by an LM3940T-3.3 3-terminal voltage regulator (REG4).

IC3 employs a 24.576MHz crystal, together with two 33pF load capacitors and a 100Ω current-limiting resistor. This provides a frequency reference for the decoder to determine the actual sampling rate of the audio signal. This is necessary in order to provide the ability to apply digital de-emphasis, since the digital filter response needs to match the sample frequency.

The DIR9001 also requires two 5% metal-film capacitors (4.7nF and 68nF) and a 1% metal-film resistor (680Ω) to form the PLL loop filter. The remaining decoder-associated components are power supply bypass capacitors.

The DIR9001 decoder converts the digital signal into a serial PCM stream (DOUT) which is passed directly to the DAC chip (IC6) itself, along with three clock signals. These are the sample clock (LRCKO), bit clock (BCKO) and master clock (SCKO). The sample clock matches the audio signal's sample rate, while the bit clock is generally 64 times that rate and is used to clock the actual data. The master clock signal is also a multiple of the sample rate – in this case, 512 times.

The master clock is used to time the DAC's oversampling, which not only makes the post-DAC analogue filters easier to design, but is also required for a delta-sigma architecture DAC such as used in this circuit.

The decoder also outputs a number of flags which are set according to the contents of the S/PDIF stream. These indicate whether there is a valid signal present (AUDIO, ERROR) and whether the audio has been pre-emphasised (EMPH). In addition, FSOUT0 and FSOUT1 indicate the detected sample rate.

There is one additional connection to the DIR9001 and that is a reset line (RST) from the microcontroller. According to the DIR9001 data sheet, an external reset is required each time power is applied. The microcontroller provides this reset signal by monitoring the 3.3V line with its ADC and holding reset low until the supply rises above 2.7V, as specified in the data sheet.

Atmel microcontroller

Controlling the whole circuit is the Atmel Mega48/V microcontroller (IC4). This is powered by the main +5V rail which comes from the power supply board described later.

Note that the switch buttons (S1 to S3) are not connected directly to the micro, but rather via some *RC* filters and a 74HC14 hex Schmitt trigger inverter (IC5). This is because when a button is pressed, the contacts tend to 'bounce' and switch rapidly on and off for a short period.

Each *RC* filter, and its associated diode, delays the button press detection long enough to allow the bounce to cease and the Schmitt trigger inverter adds hysteresis to provide a minimum 'on' pulse to the microcontroller. De-bouncing can also be performed in software, but the hardware method has its advantages and it's one less task for the microcontroller to perform.

Similarly, the IR receiver's output is fed to microcontroller IC4 via an *RC* filter and Schmitt trigger IC5c. This is done to filter out any noise generated by other IR sources in the room (apart from the remote), which could cause false triggering in the microcontroller. By filtering the IR receiver's output,

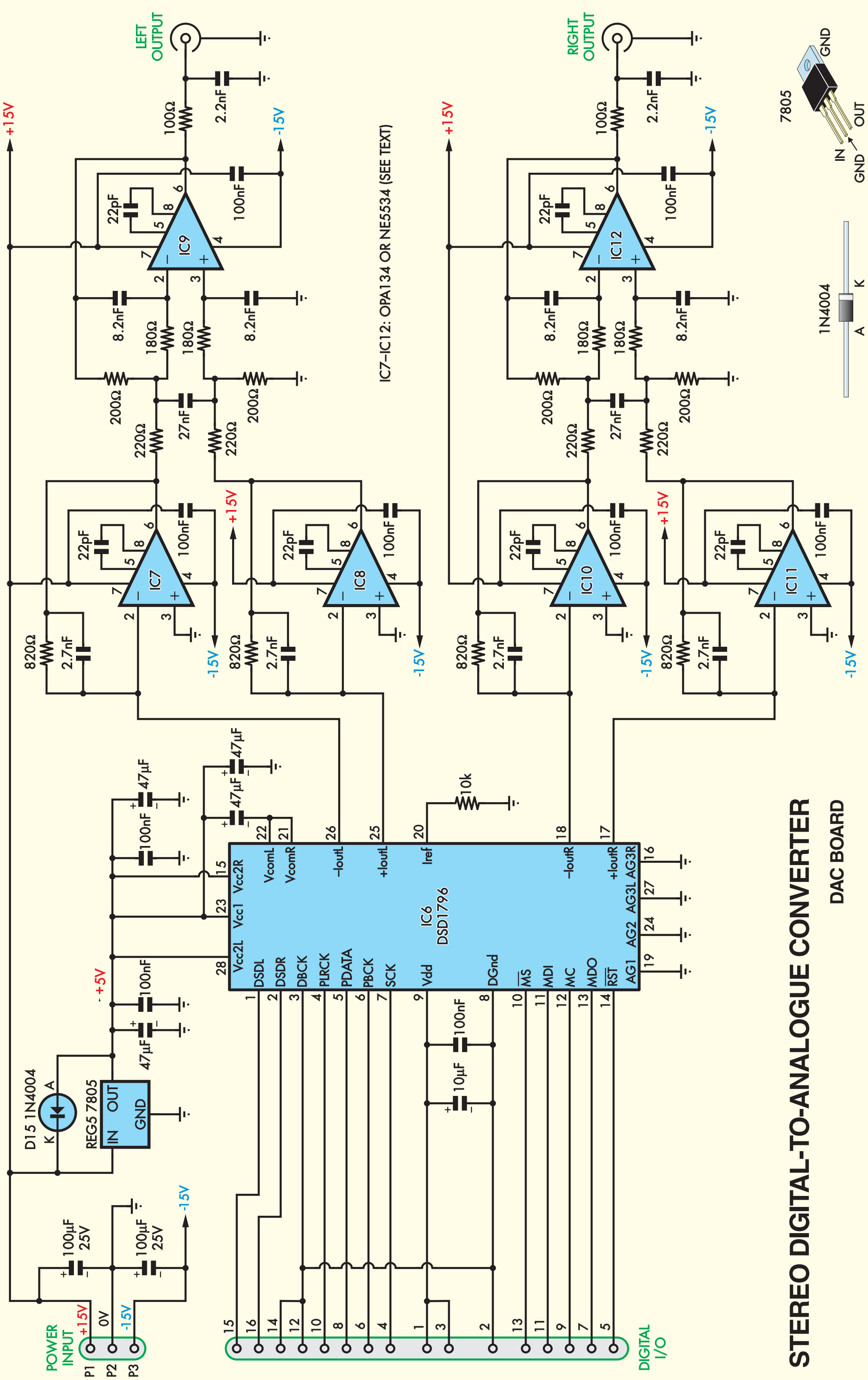
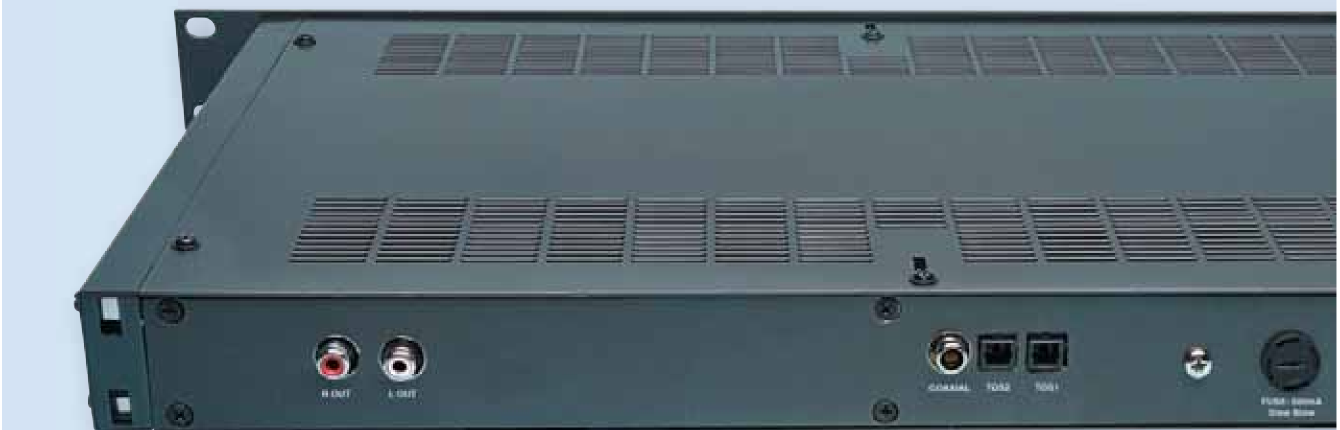


Fig.3: the DAC Board carries the DAC chip (IC6). This accepts the PCM signals from IC3 and drives current-to-voltage converter stages IC7, IC8, IC10 and IC11. These op amps in turn drive differential amplifiers IC9 and IC12, and derive the left and right channel audio outputs, respectively. The op amps are powered by ±15V rails from the power supply, while REG5 provides a +5V rail to power the DAC

The front panel is uncluttered and carries just the power switch, the three input selector pushbuttons (with their integral blue LEDs) and the valid signal and audio data indicator LEDs. The hole in the panel immediately to the left of the pushbuttons is for the IR detector (IRD1)



The rear panel carries the left and right audio output sockets, the coaxial and TOSLINK input sockets, the fuseholder and the IEC mains connector

we ensure that only signals with a minimum pulse width are detected.

Basically, the Philips RC5 code 'on-time' is a minimum of around 889µs (32 pulses at 36kHz), so the filter is designed to reject any shorter IR pulses. Again, this is not strictly necessary, but it only requires a few parts and results in more reliable remote control operation.

DAC board

Fig.3 shows the DAC Board circuit. The DAC chip itself is a Texas Instruments/Burr Brown DSD1796 (IC6) and, as previously stated, has two pairs of differential current outputs rather than voltage outputs. These are current sinks, and the current is directly proportional to the sample value after conversion.

This allows for higher performance than would be possible with a voltage-output DAC of similar design, as the external op amps can run at higher supply voltages (ie, ±15V) and with separate supply bypassing.

There are a number of support components around the DSD1796, most of them supply bypass capacitors. In addition, there is a 10kΩ resistor on pin 20 which sets the output level of the DAC, while a 47µF capacitor between pins 21 and 22 and the supply at pin 23 stabilises the DAC's internal reference voltage.

The first analogue stage following each of the four outputs from IC6 is a current-to-voltage converter and low-pass filter. Each stage consists of a single op amp (IC7, IC8, IC10 and IC11) plus an 820Ω resistor and 2.7nF capacitor. The low-pass filter is the first of three, the total effect of which rolls off the frequency response at 18dB/octave above about 24kHz.

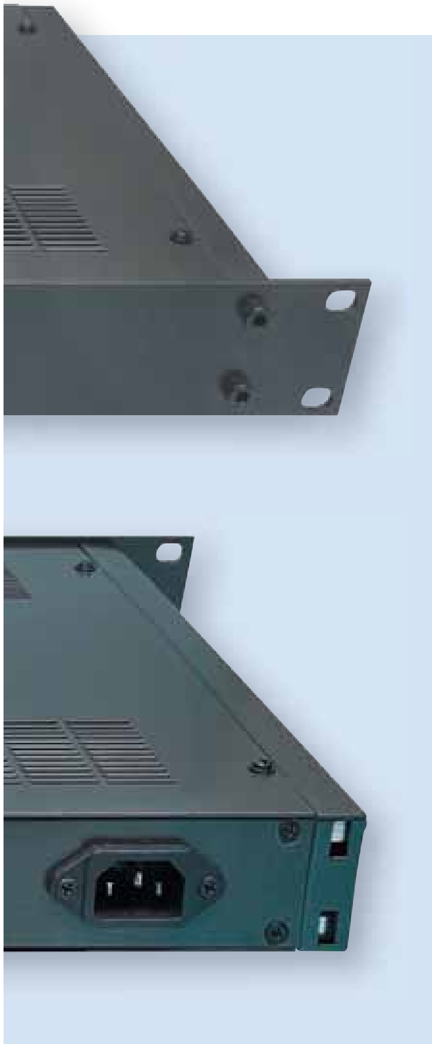
In operation, the left channel differential outputs from the DAC (IC6), are converted from current to voltage using op amps IC7 and IC8. Their outputs are in turn fed to a passive filter which consists of 220Ω resistors and a common 27nF capacitor. The filtered differential outputs are then combined by op amp IC9, which acts as a differential amplifier and active low-pass filter.

Op amps IC10, IC11 and IC12 function in exactly the same manner to produce the right channel audio output.

Output op amps

Virtually all of the circuit for the DAC Board circuit is as suggested in the Texas Instruments' data sheet for the DSD1796. However, we did make some important changes.

First, after extensive testing, we decided that OPA134 op amps are the best



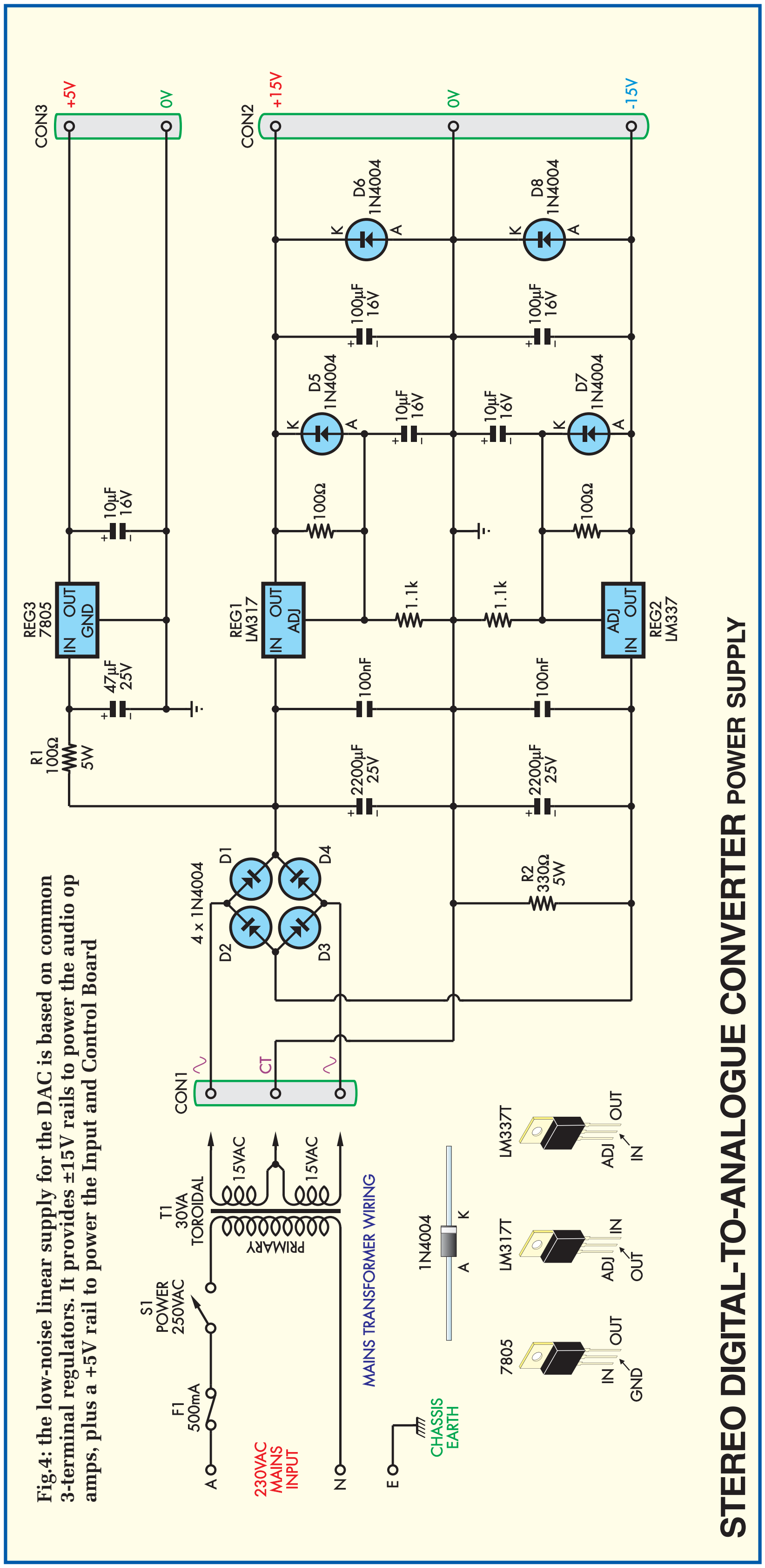


Fig.4: the low-noise linear supply for the DAC is based on common 3-terminal regulators. It provides ±15V rails to power the audio op amps, plus a +5V rail to power the Input and Control Board

available for this circuit, rather than the NE5534s specified by TI. These are from the same op amp family as the OPA2134 dual op amps used successfully in previous projects.

Alternatively, you can use NE5534s if you wish, although these will give a slight increase in harmonic distortion – from around 0.0018% or better to 0.0025% at 1kHz. In view of this, we feel that the OPA134s are worth the extra cost.

Note that six 22pF compensation capacitors are shown on the DAC circuit, but these are only necessary if you use NE5534s. They may be omitted if you are using OPA134s. However, if you install them anyway, OPA134s can still be used, as pin 5 of the OPA134 package is not internally connected.

Our second departure from the recommended Texas Instruments' DSD1796 circuit was to use a single 100nF bypass

Parts List – Stereo Digital-To-Analogue Converter (DAC)

Chassis Hardware
1 1U-high custom steel case with screened front and rear panels
1 15V+15V 30VA or 20VA toroidal transformer (Jaycar MT-2086)
1 SPST 6A 250VAC slimline rocker switch (Jaycar SK-0975)
1 male chassis-mount IEC socket (Jaycar PP-4005)
1 panel-mounting fuseholder, with 250V AC 500mA SB fuse (Jaycar SZ-2028)
1 230V AC 3-pin IEC mains power lead
5 5.3mm ID insulated crimp eyelets (Jaycar PT-4614)
4 M4 × 10mm machine screws
8 M4 nuts
8 M4 shakeproof washers
5 4.8mm fully-insulated female spade crimp connectors
20 small nylon cable ties
1 40mm-length of 16mm-ID heatshrink tubing (to cover rear of fuseholder)
1 30mm-length of 20mm-ID heatshrink tubing (to cover mains switch)

Wire and Cable
1 400mm-length heavy-duty red hook-up wire
1 240mm-length heavy-duty green hook-up wire
1 320mm-length heavy-duty black hook-up wire
1 350mm-length 7.5A 250V AC brown wire for mains cabling
1 500mm-length 7.5A 250V AC green/yellow wire for mains cabling

Input Board
*1 PC board, code 820, size 113mm × 93mm
2 PC-mount TOSLINK (optical) receivers (Jaycar ZL-3003)
1 black PC-mount RCA socket
1 14-pin PC-mount IDC header socket
1 16-pin PC-mount IDC header socket
1 14-pin IDC line socket
1 16-pin IDC line socket
1 3-pin header and shorting jumper
1 500mm-length 16-way IDC ribbon cable
1 2-way screw terminal block, 5.08mm pitch
2 14-pin DIP machined IC sockets
1 16-pin DIP machined IC socket
1 28-pin DIP machined IC socket
5 M3 × 10mm tapped spacers
10 M3 × 6mm machine screws
1 500mm-length 0.71mm tinned copper wire (for links)
1 24.576MHz crystal (HC/49 or HC/49US)

Semiconductors
1 74HCU04 hex inverter (IC1) – **do not** use 74HC04
1 74HC4052 analogue/digital multiplexer (IC2)
1 DIR9001PW Digital Audio Interface Receiver (IC3)
1 ATMEGA48V or ATMEGA48P programmed microcontroller (IC4)
1 74HC14 hex Schmitt trigger inverter (IC5)
1 LM3940T-3.3 LDO 3-terminal regulator (REG4)
2 BC327 *PNP* transistors (Q1,Q2)
5 1N4148 diodes (D9-D13)
1 1N4004 diode (D14)

Capacitors
1 470µF 6.3V electrolytic
2 22µF 6.3V electrolytic
3 1µF 6.3V electrolytic
1 470nF MKT metallised polyester
11 100nF MKT metallised polyester
1 68nF MKT metallised polyester
1 4.7nF MKT metallised polyester
1 1nF MKT metallised polyester
2 33pF ceramic
2 100pF ceramic

Resistors (0.25W, 1%)
1 1MΩ	1 680Ω
4 47kΩ	2 330Ω
6 22kΩ	1 300Ω
1 10kΩ	2 100Ω
3 2.2kΩ	

DAC Board
*1 PC board, code 821, size 94mm × 110mm
1 red PC-mount RCA socket
1 white PC-mount RCA socket
1 16-pin PC-mount IDC header socket
1 16-pin IDC line socket
1 3-way screw terminal block, 5.08mm pitch
4 M3 x 10mm tapped spacers
8 M3 x 6mm machine screws
1 500mm-length 0.71mm tinned copper wire (for links)
6 8-pin DIP machined IC sockets

Semiconductors
1 DSD1796 24-bit audio DAC (IC6)
6 OPA134 op amps (IC7 to IC12) (or use NE5534 op amps for slightly reduced performance)
1 7805 +5V regulator (REG5)
1 1N4004 diode (D15)

Capacitors
2 100µF 25V electrolytic

capacitor across the supply pins (7 and 4) of each amp. This avoids coupling supply noise into the signal ground and also provides effectively twice as much capacitance.

Third, we added a fourth low-pass (passive) filter stage to the outputs of op amps IC9 and IC12. This consists of a 2.2nF capacitor following the 100Ω current-limiting resistors and provides a rolloff (pole) at roughly 800kHz. This will slightly attenuate any high-frequency switching artefacts present on the output of the DAC. In addition, since this is a passive filter, it will be effective at filtering any very high-frequency noise which some of the active filter stages may pass through.

Power supply
As noted, this design uses a low-noise power supply. It provides regulated ±15V and +5V outputs.

The power supply board accepts a 30V AC centre-tapped input from the specified toroidal transformer, formed by joining the two 15V AC secondary windings. Diodes D1 to D4 and two 2200µF capacitors rectify and filter the input to give ±21V DC (nominal) rails.

LM317 and LM337 adjustable regulators (REG1 and REG2) generate the complementary positive and negative supply rails. Their outputs are programmed to ±15V by the 100Ω and 1.1kΩ resistors connected to their OUT and ADJ terminals. We've used adjustable regulators because the ADJ terminals can be bypassed to ground (0V) to improve ripple rejection, which we've done using 10µF capacitors. Diodes D5 and D7 provide a discharge path for the capacitors should an output be accidentally shorted to ground.

4 47µF 16V electrolytic
1 10µF 6.3V electrolytic
9 100nF MKT metallised polyester
2 27nF MKT metallised polyester
4 8.2nF MKT metallised polyester
4 2.7nF MKT metallised polyester
2 2.2nF MKT metallised polyester
6 22pF ceramic

Resistors (0.25W, 1%)

1 10kΩ	4 200Ω
4 820Ω	4 180Ω
4 220Ω	2 100Ω

Front Panel Switch Board

*1 PC board, code 822, size 103mm × 34mm
3 vertical PC-mount momentary pushbutton switches with blue LEDs (S1-S3) (Jaycar SP-0622)
1 14-pin PC-mount IDC header socket
1 14-pin IDC line socket
4 M3 × 6mm tapped nylon spacers
4 M3 × 15mm black-anodised pan-head machine screws
4 M3 star washers
4 M3 nuts
1 100mm-length 0.71mm tinned copper wire (for links)
1 100nF MKT metallised polyester capacitor

Semiconductors

1 infrared receiver module (IRD1) (Jaycar ZD-1952)
1 5mm yellow LED (LED4)
1 5mm green LED (LED5)

Power Supply Board

*1 PC board, code 823, size 54.6mm × 80mm
3 Micro-U 19°C/W TO-220 finned heatsinks
2 3-way terminal blocks, 5.08mm pitch (CON1, CON2)
1 2-way terminal block, 5.08mm pitch (CON3)
4 6mm untapped Nylon spacers
5 M3 × 6mm pan-head screws
1 M3 nut and flat washer

Semiconductors

1 LM317T adjustable positive regulator (REG1)
1 LM337T adjustable negative regulator (REG2)
1 7805 +5V regulator (REG3)
8 1N4004 diodes (D1-D8)

Capacitors

2 2200µF 25V PC electrolytic
2 100µF 16V PC electrolytic
1 47µF 25V PC electrolytic
3 10µF 16V PC electrolytic
2 100nF 50V MKT metallised polyester

Resistors (0.25W, 1%)

2 1.1kΩ
2 100Ω
1 330Ω 5W 5% (R2)
1 100Ω 5W 5% (R1)

* These boards will be available as a set from the *EPE PCB Service*

Two reverse-connected diodes, D6 and D8, across the outputs prevent their respective rails from being driven to the opposite polarity (eg, if a regulator fails), something that should never occur during normal operation.

A 7805 regulator (REG3) is used to generate the +5V rail. The 100Ω 5W resistor in line with REG3 reduces power dissipation in the regulator. As the +5V supply draws power from only the positive side of the unregulated DC input, a 330Ω 5W resistor across the negative input is included to balance the rails so that they decay at similar rates at power off.

The +5V rail provides the power to the circuitry on the main Control Board, as well as driving the LM3940T-3.3 regulator which provides power for the DIR9001 decoder. This regulator also provides a +3.3V rail (Vdd) for the DAC.

It might seem strange to use a 7805 for REG3 when we want a low-noise supply, but in fact this series of regulators has quite low output noise when used with a decent-sized output capacitor.

Finally, the +5V rail for the analogue section of the DAC does not come from REG3 on the power supply board. Instead, we use another LM7805 5V regulator on the DAC board, and this is powered from the +15V rail from the power supply. This is so that digital switching noise in the 5V digital supply does not affect the DAC's performance.

Software

The software program files for the *Stereo Digital-to-Analogue Converter* will be available from the *EPE* website at: **www.epemag.com**.

Next month, we'll show you how to assemble the four PC boards and mount them in the case.

Digital Megohm and Leakage Current Meter

By JIM ROWE

Looking for an electronic megohm and leakage current meter, for quick and easy testing of insulation in wiring and equipment? Here's a new design which allows testing at either 500V or 1000V. It can measure insulation resistances up to 999MΩ and leakage currents to below 1µA. It uses a PIC microcontroller and displays the results on a 2-line LCD panel.

DOMESTIC and industrial equipment operating from the 230V or 400V AC power mains needs to have its insulation checked regularly, so that users can be assured that it doesn't pose a shock hazard. After all, exposure to voltages of this magnitude can be fatal!

But what sort of test gear do you need to carry out this type of safety check? You'll get a fair idea by reading the text in the 'Insulation testing' panel on the opposite page.

In a nutshell, you need a portable and isolated meter that is capable of providing a nominal test voltage of 500V or 1000V DC, and able to measure leakage current or insulation resistance or both.

Our new Megohm and Leakage Current Meter design is intended to meet these requirements. It is compact, portable and isolated and provides a choice of either 500V or 1000V DC as the test voltage.

It also allows you to measure insulation resistances from below 1MΩ up to virtually 999MΩ, as well as leakage currents from below 1µA to over 100µA (103µA, to be precise).

We should point out that because it can only measure leakage currents up to 103µA, it will indicate that Class I equipment (with earthed external metalwork) is effectively unsafe if it has a leakage current of more than 100µA – even though, strictly speaking, this kind of equipment is still regarded as 'safe' providing its leakage current is below 5mA.

So the test performed by this meter is more rigorous than the official safety standards – but where safety is involved it's better to be too tough than not tough enough, surely?

The new meter is easy to build, with most of the major components mounted on a small PC board. This fits inside a compact UB1-size plastic box, along with a small power transformer used in the test voltage generation circuit and the 4-AA battery holder used to supply the meter's power.

Warning – read this first!

1) This is an educational project that lets you investigate electrical safety and insulation in portable equipment. It is NOT a substitute for a professionally built and certified 'PAT' tester.
2) It was designed for use in Australia / New Zealand. While their requirements are very similar to the those in the UK, you cannot assume they are identical.
3) If you are in any doubt about the safety of a piece of equipment then you MUST get it checked professionally.
4) This is NOT a beginner's project – only use it if you know what you are doing or are suitably supervised.

How it works

The block diagram, Fig.1, shows what is inside the new meter. It's split into two distinct sections: the left-hand side generates the test voltage of 500V or 1000V, while the metering section on the right-hand side is used to measure any leakage current which flows between the test terminals, and from this calculates the external resistance connected between them.

In more detail, the test voltage generation section has a DC-AC inverter which converts 6V DC from the battery into AC, so it can be stepped up to a few hundred volts AC. This is fed to a voltage-multiplying rectifier circuit to produce the 500V or 1000V DC test voltage.

We use a negative feedback loop to control the inverter's operation and maintain its output voltage to the correct level. This works by using a high-ratio voltage divider (RD1 and RD2) to feed a small proportion of the high voltage DC output back to one input of comparator IC2b, where it is compared with a 2.50V voltage reference.

The comparator is then used to turn off the DC/AC inverter when the high voltage reaches the correct level and to turn the inverter on again when the voltage is below the correct level.

The basic voltage divider using RD1 and RD2 alone is used to set the high voltage level to 500V, with multiturn trimpot VR1 allowing the voltage to be set very closely to this level. To change the test voltage level to 1000V, switch S1 is used to connect RD3 in parallel with RD2, doubling the division ratio of the divider and hence doubling the output voltage maintained by the feedback loop.

Note that the inverter only operates to generate the 500V or 1000V test voltage when TEST button switch S2 is pressed and held down. As soon as the button is released, the inverter stops and the high voltage leaks away via RD1 and RD2/RD3. This is a safety feature and also a simple way to achieve maximum battery life.

Meter section

Referring back to Fig.1, the meter section is at lower right. It uses a 10kΩ resistor as a 'shunt', to sense any leakage current (I_L) which may flow between the test terminals. Since the shunt has a value of 10kΩ, this means that a leakage current of 100µA produces a voltage drop of 1.00V. It is the voltage across this resistor which we measure, to determine the leakage current.

First, the voltage is fed through a DC amplifier (IC2a), where it is given a voltage gain A of 3.1 times. Then it is passed to IC3, a PIC16F88 microcontroller, which is used here as a 'smart' digital voltmeter.

The amplified voltage from IC2a is fed to one input of the ADC (analogue-to-digital converter) inside the micro (IC3), where it is compared with a reference voltage of 3.2V. The digital output of the ADC is then mathematically scaled, to calculate the level of the leakage current in microamps (µA). The micro is then also able to use this calculated current level to work out the insulation resistance, because it can sense the position of switch S1 and hence 'knows' whether the test voltage being used is 500V or 1000V.

So all it has to do is calculate the total resistance, which will draw that level of leakage current from the known test voltage, and then subtract the 'internal' 10MΩ and 10kΩ resistors from this total value to find the external resistance between the test terminals. The calculated leakage current and insulation resistance values are then displayed on the LCD panel, along with the test voltage of 500V or 1000V.

The 10MΩ resistor connected between the high voltage generation circuit and the positive test terminal (ie, inside the meter), is included mainly to limit the maximum current that can be drawn from the HV generator – even in the event of a short circuit between the test terminals. In fact it's the 10MΩ resistor which limits the maximum current to 100µA with the 1000V test voltage, or 50µA at 500V.

Another function of the 10MΩ resistor is to make the meter safer to use; if you accidentally become connected between the test terminals yourself, you will get a shock, but it won't kill you. Mind you, that shouldn't happen, because you would have to be simultaneously holding down the TEST button to get a shock.

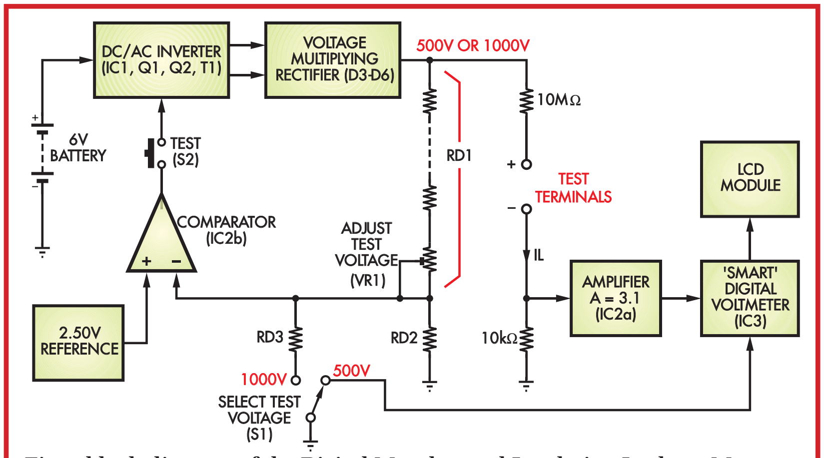


Fig.1: block diagram of the Digital Megohm and Insulation Leakage Meter

Insulation testing

Testing the insulation of mains-powered cables and equipment is an important step in ensuring that they are safe to use and don't pose a shock hazard.

According to the Australian and New Zealand standards for safety inspection and testing of electrical equipment (AS/NZS 3760:2003), tests on the insulation of 'domestic' cables and equipment operating from 230V AC should be carried out with a testing voltage of 500V DC. Similarly, the recommended testing voltage for insulation tests on 'industrial' equipment like ovens, motors and power converters operating from 3-phase 415V AC is 1000V DC.

Insulation tests on domestic 230V AC equipment can be performed by measuring either the leakage current or the insulation resistance. For Class I equipment with accessible earthed metal parts, the leakage current should be no greater than 5mA, except for portable RCDs (residual current devices) where it should not be greater than 2.5mA. The insulation resistance for these devices should be not less than 1MΩ, or not less than 100kΩ for a portable RCD.

For Class II (double-insulated) equipment, the insulation resistance with the power switch 'on' measured between the live supply conductors (connected together) and external unearthed metal parts should again be not less than 1MΩ.

The same insulation resistance figure of 1MΩ applies to extension cables and power boards (between the live conductors and the earth conductor), to power packs (between the live input pins and both output connections) and also to portable isolation transformers (between the primary winding and external earthed or unearthed metal parts, between primary and secondary windings, and also between the secondary winding and external earthed or unearthed metal parts).

As you can see from the above explanation of the way the meter's smart voltmeter works, there is no problem having the 10MΩ current limiting resistor in series with the test terminals, just as there's no problem using a 10kΩ current measuring 'shunt'. The program inside the PIC knows that both of these resistors are in series with the external resistance being measured and simply subtracts 10.01MΩ from the total resistance to find the external value.

Circuit details

The full circuit diagram for the Digital Megohm and Leakage Current Meter is shown in Fig.2. The DC/AC inverter section of the circuit uses IC1, a quad Schmitt NAND gate, to drive switching transistors Q1 and Q2. When the inverter is operating, the transistors switch about 5.6V DC alternately to either end of the low voltage winding of a standard mains transformer, T1.

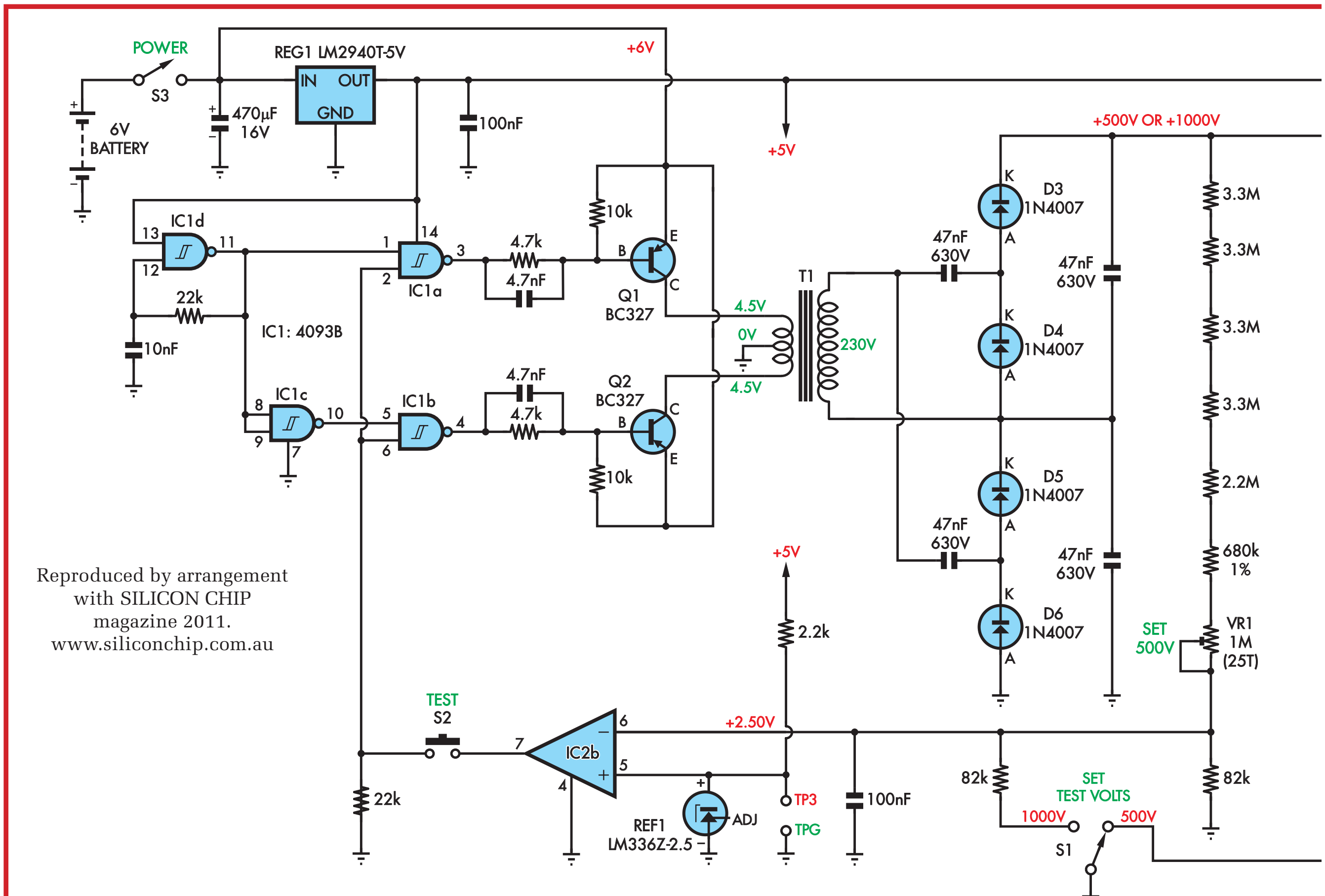
This is used as a step-up to produce a much higher AC voltage to feed the voltage-multiplying rectifier comprising diodes D3 to D6 and their associated 47nF/630V capacitors.

Oscillator IC1d runs continuously at about 6kHz, and its output is inverted by IC1a and IC1c. IC1c drives inverter IC1b, while IC1a and IC1b apply the alternating signals to the bases of transistors Q1 and Q2. But gates IC1a and IC1b have their pins 2 and 6 pulled down by a common 22kΩ resistor, and so they are disabled until the TEST button (S2) is pressed.

When that happens, comparator IC2b will pull IC1a's pin 2 and IC1b's pin 6 high and the inverter will run until the output of the voltage multiplying rectifier reaches the correct voltage level. As soon as the high voltage output reaches the correct level, the comparator's output will switch low and gates IC1a and IC1b will be turned off, stopping the inverter, even if switch S2 is still being held down. The feedback network will maintain this process as long as S2 is pressed.

The collectors (C) of Q1 and Q2 are supplied with the full battery voltage. All of the remaining circuitry in the meter operates from a regulated +5V supply line, derived from the battery via an LM2940 regulator, REG1.

The metering side of the circuit is performed by the PIC16F88 micro, IC3. The voltage developed across the 10kΩ 'shunt' resistor (in response to the current between the test terminals) is amplified by op amp IC2a, which has a gain of 3.1.



DIGITAL MEGOHM & INSULATION LEAKAGE METER

Fig.2: the circuit is essentially two parts – the left side generating the high voltage needed to perform the tests and the right side using this voltage to perform the required measurements

The amplified voltage is fed to pin 1 of IC3 (AN2) which is configured as an ADC input. The 3.2V reference voltage for the ADC is fed to pin 2 of IC3, being derived from the 5.0V supply line via the voltage divider using the 3.3kΩ, 5.6kΩ and 270Ω resistors.

As noted before, the ADC inside IC3 measures the voltage applied to pin 1 by comparing it with the reference voltage fed to pin 2. The micro then calculates the leakage current through the test terminals.

Because it is able to sense the position of test voltage selector switch S1 (high or low) via pin 3 (RA4), it is able to deduce the actual test voltage (500V or 1000V) and hence calculate the total resistance connected across it via the test terminals. Finally, it works out the external resistance between the terminals by subtracting the 10.01MΩ internal resistance.

The calculated current and resistance values are then displayed on the LCD module, along with the test voltage being used.

In this circuit, IC3 is using its internal clock oscillator, running at very close to 8MHz. This gives an instruction cycle time of 2MHz, which may be monitored using a scope or frequency counter at test point TP2.

The micro drives the LCD module in the standard 'four-bit nibble' fashion, which involves a minimum of external components.

Trimpot VR2 allows the LCD module's contrast to be adjusted for optimum visibility, while the 22Ω resistor connected to pin 15 sets the current level for the module's inbuilt LED back-lighting. This was chosen as a compromise between display brightness and battery life.

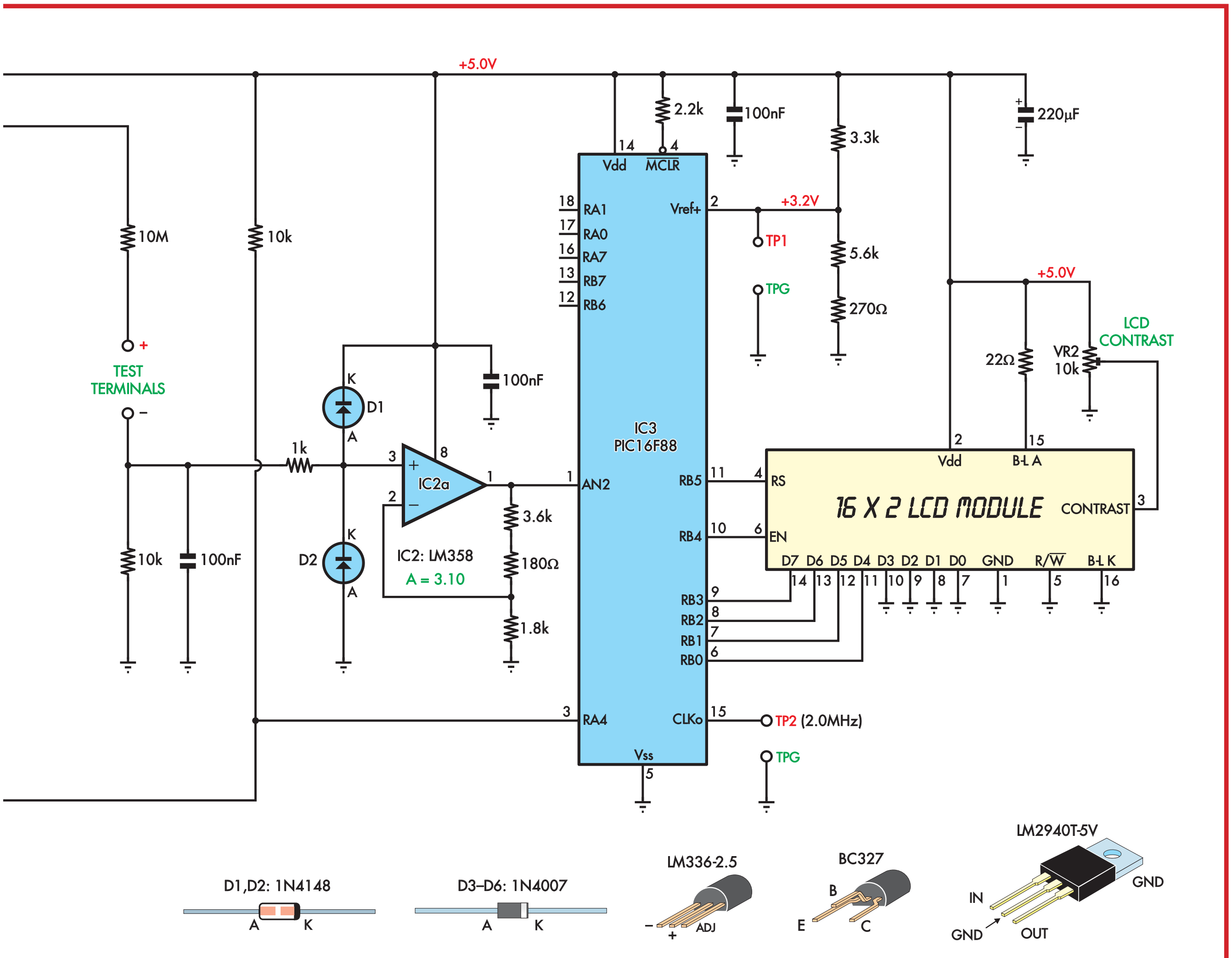
Software

The software program files for the Stereo Digital Megohm and Leakage Current Meter will be available from the *EPE* website at: **www.epemag.com**

Construction

Most of the components are mounted directly on the PC board. This measures 84mm × 102mm and is coded 818. This board is available from the *EPE PCB Service*.

The only components not mounted on the board are transformer T1 and the 6V battery holder, which are both mounted in the lower part of the case, the test terminals and switches S1 to S3. The board assembly mounts



behind the lid via four 25mm long tapped spacers.

The diagram of Fig.3 shows all of the components mounted on the board, together with the wiring to the off-board transformer.

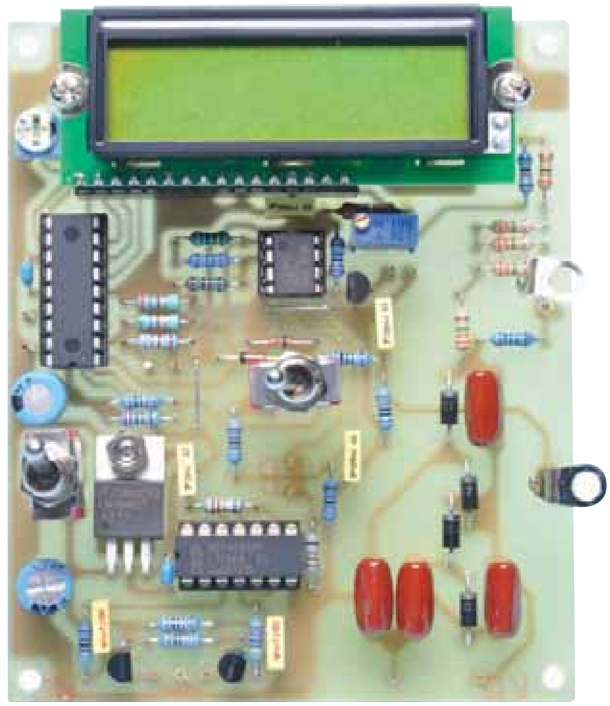
There are only two wire links to be fitted, and these are best fitted first so they won't be forgotten. One goes to the left of board centre, while the other goes just below the position for IC2. After both links are fitted you can fit the six terminal pins for test points TP1 to TP3 and their reference grounds, followed by the sockets for IC1, IC2 and IC3, taking care with their orientation.

Next, fit all of the fixed resistors, taking particular care to fit each value in its correct position. Follow these with the two trimpots, making sure you fit VR1 with the correct orientation, as shown in Fig.3.

The capacitors are next, starting with the lower value ceramic and metallised polyester caps and following these with the two polarised electrolytics – again matching their orientation to that shown in Fig.3. The 47nF 630V polyester caps can be fitted also at this stage.

Next, fit diodes D1 to D6, taking care to orientate them correctly. Make sure you fit the 1N4007 diodes in positions D3 to D6. Then install transistors Q1 and Q2, plus the LM336Z-2.5 voltage reference, REF1.

Then fit the LM2940 regulator, REG1. This TO-220 package mounts flat against the top of the board, with its leads bent down by 90° about 6mm from the body, so they pass down through the board holes. The regulator is then attached to the board using a 6mm long M3 screw and nut, passing through the hole in its tab. The screw and nut should be tightened to secure the regulator in position *before* its leads are soldered to the pads underneath.



A same-size photo of the PC board, assembled and ready for mounting in the box. The two test terminals and the 'TEST' pushbutton switch are not shown here, as they mount on the front panel and connect by wires. Compare this photo to Fig.3, far right, which shows the complete component layout/ wiring (in this case with the test terminals and 'TEST' switch)

LCD mounting

The final component to be mounted directly on the board is the 16-way length of SIL (single in-line) socket strip, used as the 'socket' for the specified LCD module.

Once this is fitted and soldered, you can fasten two 12mm long M3 tapped nylon spacers to the board in the module mounting positions (one at each end) using a 6mm M3 screw passing up through the board from underneath.

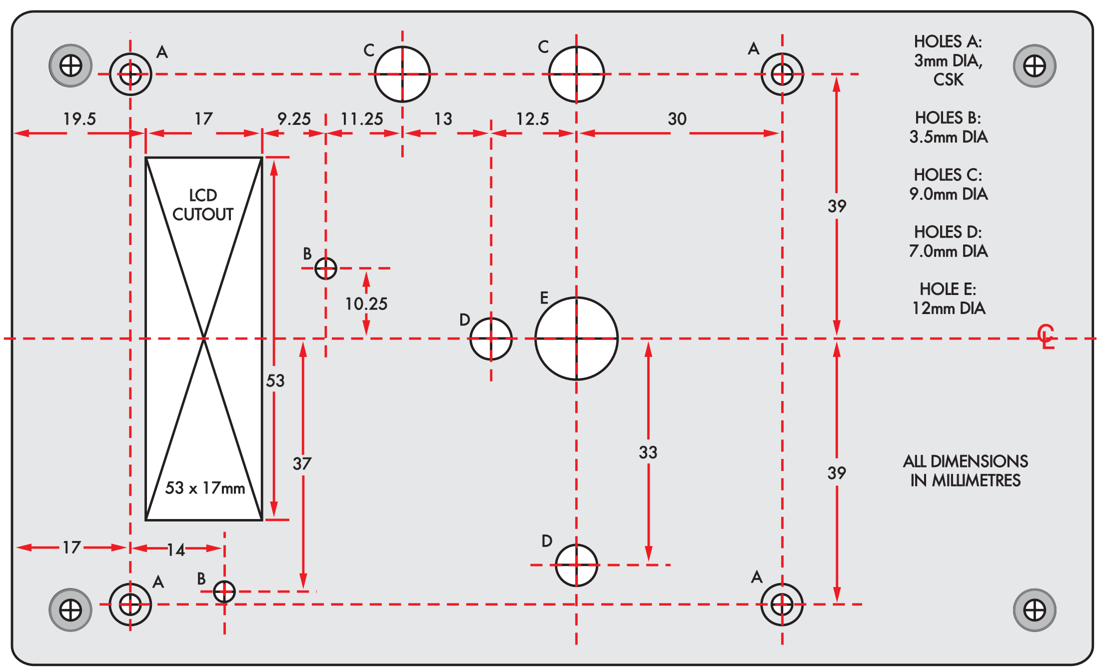
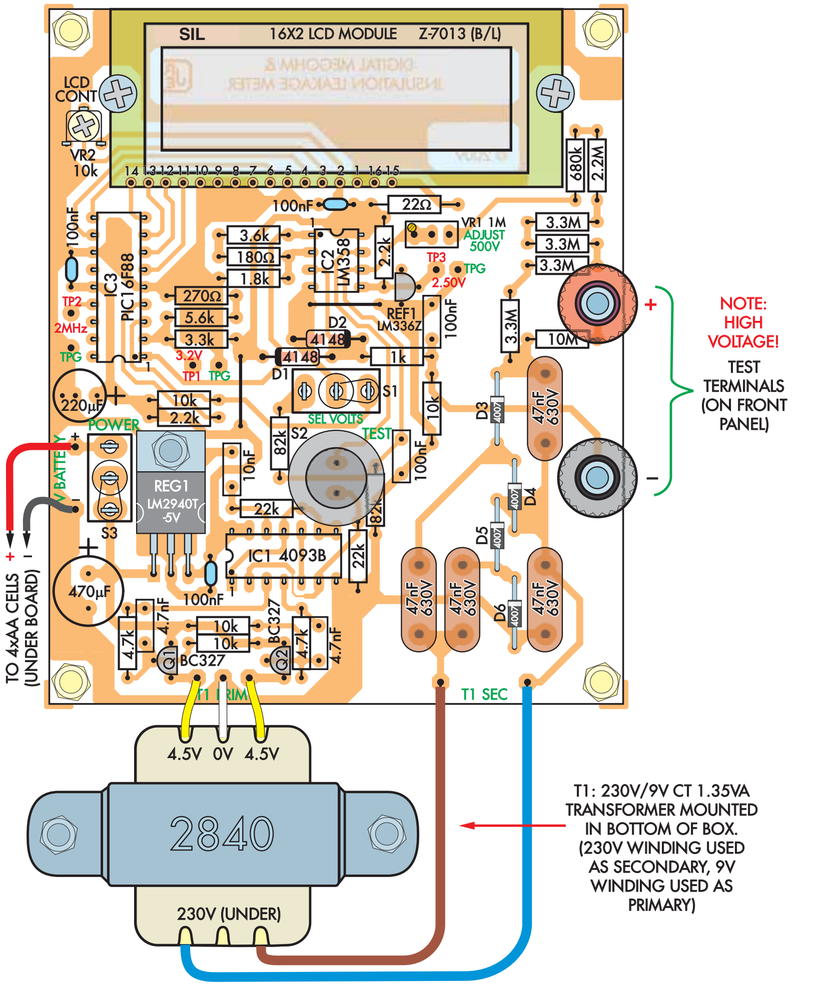


Fig.4: use a photocopy of this diagram as a template to mark out the front panel holes before drilling



PARTS LIST

1 PC board, code 818, available from the *EPE PCB Service*, size 84mm × 102mm
1 UB1-size plastic box, 157mm × 95mm × 53mm
1 LCD module, 2 lines × 16 chars, with LED back-lighting (SIL version)
1 power transformer, 9V CT secondary at 150mA or 1.35VA (eg 2840 type)
4 AA cell battery holder, flat type, with battery snap lead
2 mini SPDT toggle switch (S1, S3)
1 SPST pushbutton switch (S2)
2 binding post/banana jacks (1 red, 1 black)
2 4mm diameter solder lugs
1 16-pin length of SIL socket strip
1 16-pin length of SIL pin strip
1 18-pin IC socket
1 14-pin IC socket
1 8-pin IC socket
4 25mm long M3 tapped metal spacers
2 12mm long M3 tapped nylon spacers
9 6mm long M3 pan-head screws
4 6mm long M3 machine screws, countersunk head
2 10mm long M3 machine screws, countersunk head
3 M3 nuts with star lockwashers
6 1mm diameter PC board terminal pins

Semiconductors

1 4093B quad Schmitt NAND gate (IC1)
1 LM358 dual op amp (IC2)
1 PIC16F88 programmed microcontroller (IC3)
1 LM2940T LDO +5V regulator (REG1)
1 LM336Z-2.5 +2.5V reference (REF1)
2 BC327 *PNP* transistors (Q1,Q2)
2 1N4148 signal diodes (D1,D2)
4 1N4007 1000V/1A diodes (D3-D6)

Capacitors

1 470mF 16V radial electrolytic
1 220mF 16V radial electrolytic
2 100nF MKT metallised polyester
3 100nF multilayer monolithic ceramic
4 47nF 630V metallised polyester
1 10nF MKT metallised polyester
2 4.7nF MKT metallised polyester

Resistors (0.25W 1% unless specified)

1 10MΩ	1 680kΩ	2 82kΩ
2 22kΩ	4 10kΩ	1 5.6kΩ
2 4.7kΩ	1 3.6kΩ	1 3.3kΩ
2 2.2kΩ	1 1.8kΩ	1 1kΩ
1 270Ω	1 180Ω	

4 3.3MΩ 5% carbon film 0.5W
1 2.2MΩ 5% carbon film 0.5W
1 22Ω 5% carbon film 0.5W
1 1MΩ 25-turn trimpot, top adj. (VR1)
1 10kΩ mini horizontal trimpot (VR2)

Then plug a 16-way length of SIL pin strip into the socket strip you have just fitted to the board. Make sure the longer ends of the pin strip pins are mating with the socket, leaving the shorter ends uppermost to mate with the holes in the LCD module.

Next, remove the LCD module from its protective bag, taking care to hold it between the two ends so you don't touch the board copper. Lower it carefully onto the main board so the holes along its lower front edge mate with the pins of the pin strip, allowing the module to rest on the tops of the two 12mm long nylon spacers. Then you can fit another 6mm M3 screw to each end of the module, passing through the slots in the module and mating with the spacers.

When the screws are tightened (not over tightened!) the module should be securely mounted in position.

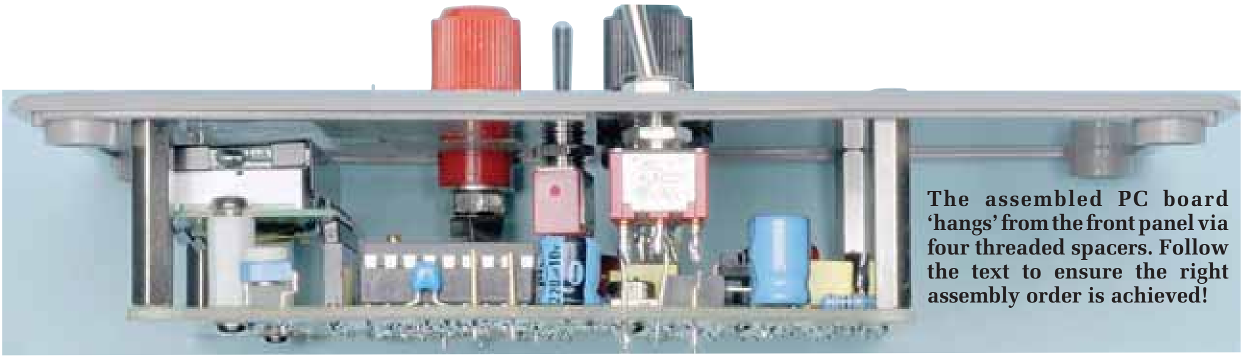
The final step is to use a fine-tipped soldering iron to solder each of the 16 short pins of the pin strip to the copper pads on the module, to complete its interconnections. Check that there are no shorts between pads.

After this is done, you can plug the three ICs into their respective sockets, making sure to orientate them all as shown in Fig.3.

Attach a 25mm long mounting spacer to the top of the board in each corner, using 6mm long M3 screws. Then the board assembly can be placed aside while you prepare the case and its lid.

Preparing the case

Two holes need to be drilled in the lower part of the case, to take the mounting screws for transformer T1. These should be 3mm in diameter, spaced 47mm apart and 20mm up from the end of the case, which will become the meter's lower end. The battery holder can be held securely in place using two strips of 'industrial' double-sided adhesive foam – see Fig.5 and photo.



The assembled PC board 'hangs' from the front panel via four threaded spacers. Follow the text to ensure the right assembly order is achieved!

The lid needs to have a larger number of holes drilled, plus a rectangular cut-out near the upper end for viewing the LCD. The location and dimensions of all these holes are shown in the diagram of Fig.4. You can use a photocopy of it as a drilling template. The 12mm hole for S2 and the 9mm holes for the test terminals are easily made by drilling then first with a 7mm twist drill and then enlarging them to size carefully using a tapered reamer.

The easiest way to make the rectangular LCD viewing window is to drill a series of closely-spaced 3mm holes just inside the hole outline, and then cut between the holes using a sharp chisel or hobby knife. Then the sides of the hole can be smoothed using a medium file.

The artwork of Fig.6 can be used as the front panel label. This can be colour photocopied from the magazine. The resulting copy can be laminated and attached to the front of the lid (or covered with self-adhesive clear film) for protection against finger grease.

You might also like to attach a 60mm × 30mm rectangle of 1mm to 2mm thick clear plastic behind the LCD viewing window, to protect the LCD from dirt and physical damage. The 'window pane' can be attached to the rear of the lid using either adhesive tape or epoxy cement.

Once your lid/front panel is finished, you can mount switches S1 to S3 on it using the nuts and washers supplied with them. These can be followed by the binding post terminals. Tighten the binding post mounting nuts quite firmly, to make sure that they don't come loose with use. Then use each post's second nut to attach a 4mm solder lug to each, together with a 4mm lockwasher to make sure they don't work loose either.

Now you can turn the lid assembly over and solder 'extension wires' to the connection lugs of the three switches and to the solder lugs fitted to the rear of the binding posts. These wires should all be about 30mm long and cut from tinned copper wire (about 0.7mm diameter). Once all of the wires are attached, they should be dressed vertical to the lid/panel so they'll mate with the corresponding holes in the PC board, when the two are combined.

Next, mount transformer T1 at one end of the case, with its low voltage winding connections towards the top and the high voltage connections towards the bottom, as in Fig.5. Secure the transformer in position using two 10mm-long M3 machine screws with flat washers, star lockwashers and M3 nuts, tightening both firmly to make sure the transformer cannot work loose.

The 4-AA cell battery holder can also be mounted in the upper end of the case using double-sided adhesive foam, with its battery snap connections at the lower end.

Next, solder the bared ends of the battery clip lead wires to their connection pads on the PC board, just to the left of the position for power switch S3. The leads from transformer T1 can also be connected to the connection pads along the lower edge of the PC board, with the three low voltage winding leads connecting to the pads on the left and the two high voltage winding leads to the pads on the right, as shown in Fig.3.

Now you can attach the PC board assembly to the rear of the lid/front panel. You have to line up all of the extension wires from switches S1 to S3 and the two test terminals with their matching holes in the PC board, as you bring the lid and board together. Then you can secure

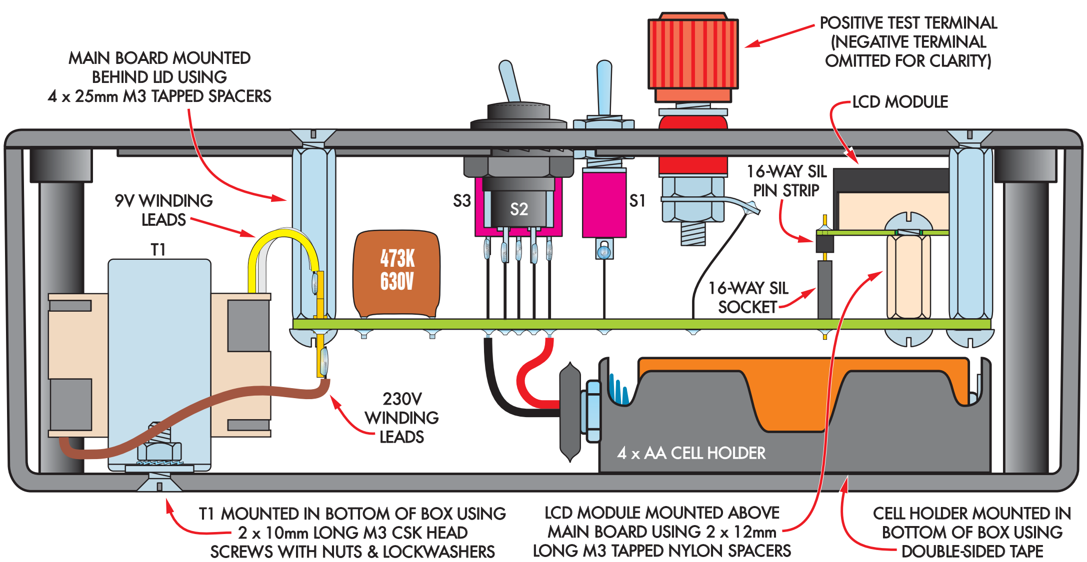


Fig.5: the assembled project inside a UB1-size box. Note that this does not show the negative test terminal (which would hide S2 and S3)

Here's how it all fits together inside a UB1 box. The power transformer and battery holder are the only components not mounted on the PC board

the two together using four 6mm long countersink head machine screws.

Next, turn the complete assembly over and solder each of the switch and terminal extension wires to their board pads. Fit four AA alkaline cells into the battery holder and your new Megohm/Insulation Meter is ready for its initial checkout.

Initial checkout

If you set switch S3 to its ON position, a reassuring glow should appear from the LCD display window – from the LCD module's back-lighting, and you should also see the meter's initial greeting 'screen'. You may need to adjust contrast trimpot VR2, until you get a clear and easily visible display. (VR2 is adjusted through the small hole just to the left of the LCD window.)

After a few seconds, the LCD should change to the meter's measurement 'screen', where it displays the current test voltage setting, together with the measured leakage current and resistance (as shown in the opening photograph).

At this stage, it will show a leakage current of 000µA and a resistance of 999MΩ, for two reasons: (1) because the test voltage isn't actually generated until you press the TEST button and (2) you haven't connected anything between the two test terminals at this stage, to draw any current.

Just to make sure though, try switching voltage selector switch S1 to the other position. You should find that the test voltage setting displayed on the top line of the LCD screen changes to match. If so, it will show that your Digital Megohm and Insulation Meter is working correctly.

This being the case, switch off the power and complete the final assembly by lowering the lid/PC board assembly into the case and securing the two together using the four small self-tapping screws supplied.

Setting the test voltages

The test voltage levels are set with trimpot VR1. This is adjusted via a small screwdriver through the small hole just below the LCD window. But how do we get the meter to measure the test voltages itself? Simply by connecting a short piece of wire between the two test terminals, as a short circuit. This temporarily changes the meter into a 0-1000V voltmeter, to read the test voltage on the leakage current range.

So, to set the test voltages, fit the shorting wire between the test terminals and then switch S1 to the '1000V' position. Then switch the meter on, and once it is displaying the measurements screen press and hold down the TEST button (S2). The LCD should show a 'current' of close to 100µA, corresponding to a test voltage of 1000V. If it indicates a figure either higher or lower than this, all you have to do is adjust trimpot VR1 with a small screwdriver until the reading changes to 100µA (=1000V).

To make sure that you have made the setting correctly, try switching voltage selector switch S1 to the '500V' position. You should find that the LCD reading changes to 50µA(=500V). If so, your meter is now fully set up.

Remove the short circuit between the test terminals and your meter is ready for use. ***EPE***

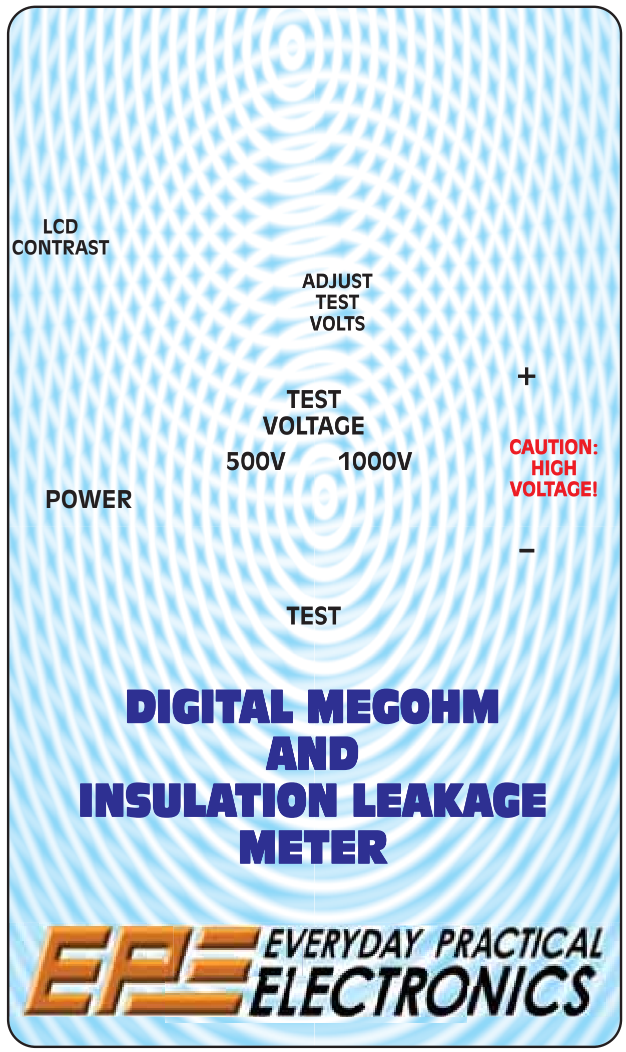
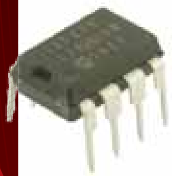


Fig.6: same-size artwork for the front panel. This does not have the hole positions shown, so all screws are hidden once it is glued in place

Integrated Circuits



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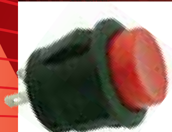

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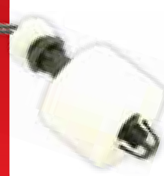

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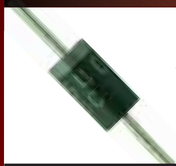

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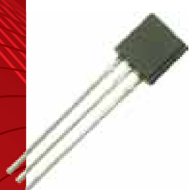

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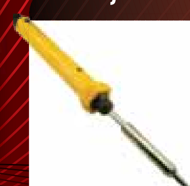

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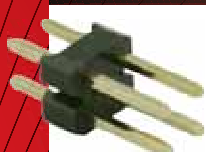

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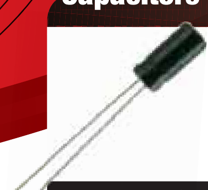

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A Deluxe 3-channel UHF Rolling Code Remote Control

Part 2 – by John Clarke

Last month, we introduced our new high security remote control and got as far as completing both the receiver/relay driver and transmitter. This month we'll put it all together and get the two parts talking to each other – securely!

WE'RE ASSUMING that you've completed construction, including setting the transmitter and receiver identities, as detailed last month. You will also have given both PC boards a visual check and made sure that there are no solder bridges (except the deliberate ones in the transmitter identity!) or breaks, bad joins or errors.

Testing

With IC1 out of its socket, connect a 12V plugpack or other 12V supply via the power socket. Check that LED5 lights and that there is about 5V between pin 5 and pin 14 of the IC1 socket. The voltage could range from 4.85V to 5.15V.

If this is correct, switch off power and plug in IC1. Place the LK1 jumper link in the 'out' position and rotate VR1, VR2 and VR3 fully anticlockwise to set the momentary period at minimum.

Apply power and press switches S1, S2 and S3. This should activate RELAY1, RELAY2 and RELAY3 for about a quarter of a second each, with LED1, LED2 and LED3 lighting up during this period. If this test is OK, you can assume the circuit is working correctly. Now it's time to set the operation of the relays.

Momentary or toggle

Note that while we have made two of the relay 'NC' connections available, these may not be of much use in the momentary mode. However, they could be quite useful in the toggle mode.

Setting the relays for momentary or toggle mode is done in this

We presented construction details for the two PC boards last month. Here's what our completed project looks like. The panel on the receiver is actually an overhead projector transparency glued to the inside of the lid, so you can see the LEDs inside the case

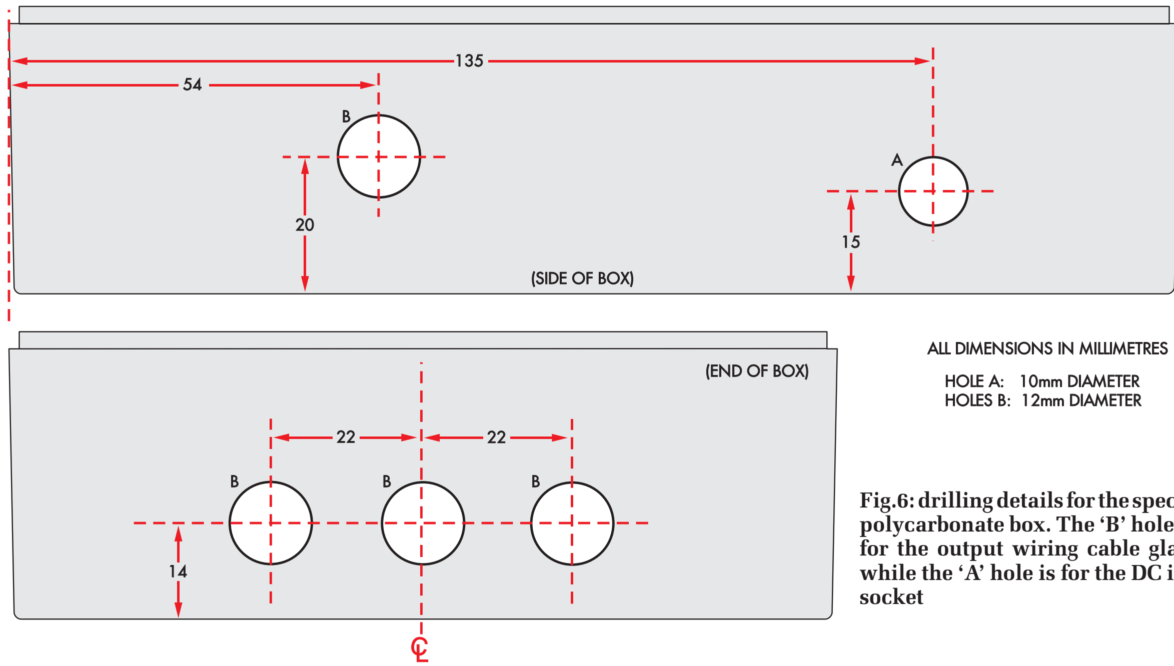


Fig.6: drilling details for the specified polycarbonate box. The 'B' holes are for the output wiring cable glands, while the 'A' hole is for the DC input socket

way. Place the LK1 jumper in the 'in' position. Set BCD1 switch to the number of the relay that you wish to change operation. Then press S2 momentarily. (Do not press S1 or you will lockout the transmitter with the identity number that is set on BCD1 instead). For example, if you want RELAY1 to be changed from momentary to toggle operation, set BCD1 to position 1. Then press S2. Now you can place the LK1 jumper in the 'out' position and by pressing S1 you will have RELAY1 operating in the toggle mode.

To revert to momentary mode, place LK1 in the 'in' position, set BCD1 to '1' and press S2 again. Placing LK1 in the out position and pressing S1 will show that RELAY1 now operates in momentary mode.

Momentary period

Momentary period for each of the relays is set with its associated trimpot (ie, RELAY 1 is set by VR1; RELAY2 by VR2 and RELAY3 by VR3). Periods are adjustable from 0.26s to 2s in 0.26s steps, then in 1s steps to 10s and in 15s steps to 4.4 minutes. Table 2 shows a sample of the settings available and the approximate voltage that is measured at the trimpot test points for various timeouts. The voltages can be measured between TP GND and the appropriate test point (TP1, 2 or 3) for VR1, VR2 and VR3 respectively.

If you want only short timeouts, it is easier to simply experiment with the position of the trimpot for the desired timeout. For longer timeouts, you will save time in finding the right setting for the trimpot by measuring the voltage and comparing this to the timeouts from Table. 2.

Note that the minimum period of 0.26s will be set for the first 10° to 20° of trimpot movement clockwise from its fully anticlockwise point. This is done so that it will be possible to finely set the increments of 0.26s at the lower end of travel. Trimpots tend to jump in value at their travel extremes, and having this dead band of operation moves any changes in time settings into the more linear section of the trimpot.

At this stage, if the transmitter identity is '0', pressing the switches on the transmitter should activate the relays on the receiver. This is only if you have not used the randomise function on the transmitter. Also, the transmitter needs to be at least 1m from the receiver to work correctly – any closer may overload it. If you have activated the randomise function on the transmitter, then you will need to register the transmitter – see the registering section.

Randomising

Randomisation of the transmitter ensures that it uses a unique set of parameters to calculate the rolling code. This procedure is a vital step in ensuring security because the default parameters are the same for every transmitter.

You need to personalise the parameters to prevent another transmitter that has the same identity from possibly operating your receiver. If randomisation is not done, there is the risk that someone else's transmitter that also has not been randomised will operate your receiver.

To randomise a transmitter, simply connect the jumper shunt into the LK1 position. The transmit LED will flash at a four per second rate for the duration. Wait for a short period (say several seconds to a few minutes) then remove the jumper. To prevent losing the jumper, it can be stored in the 'keeper' position when finished.

Parameters are altered every 40μs, that is 25,000 times per second, so they will end up being different for each transmitter. The randomisation relies on the fact that it would be impossible to randomise two transmitters over exactly the same period by plugging and unplugging the jumper plug to within 40μs of the same period.

Add this to the fact that we do not specify a particular period to run the randomisation (as we leave this up to each individual person); a unique set of rolling code parameters is ensured.

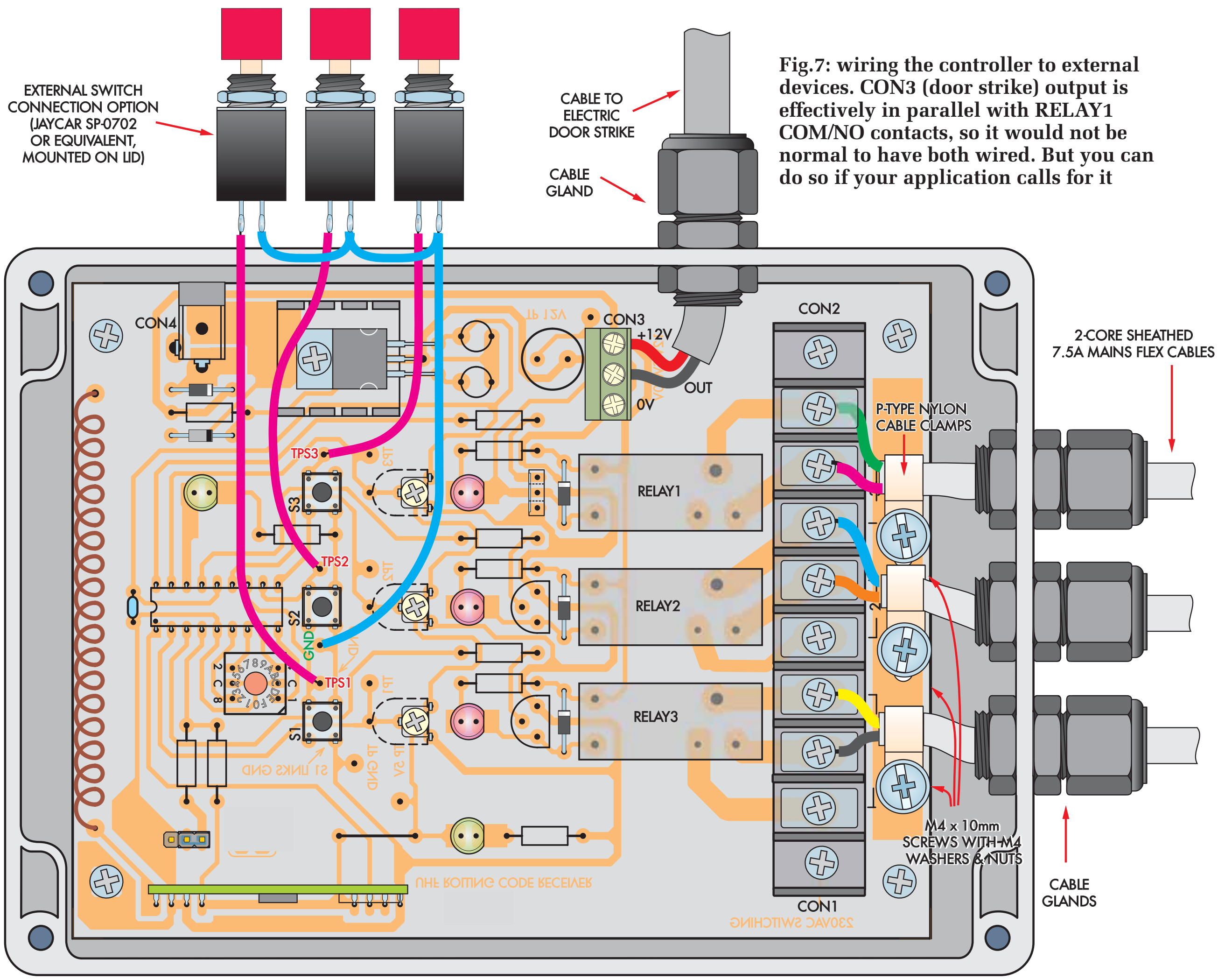


Fig.7: wiring the controller to external devices. CON3 (door strike) output is effectively in parallel with RELAY1 COM/NO contacts, so it would not be normal to have both wired. But you can do so if your application calls for it

Registering

After randomisation, the transmitter needs to be registered with the receiver in order to work. Both transmitter and receiver must be readied for this. Place the transmitter jumper in the LK2 position and at the receiver, place the LK1 jumper in the 'in' position. Now press and hold S3 on the receiver and then momentarily press S3 on the transmitter (with the transmitter about 1m away from the receiver).

The acknowledge LED on the transmitter will flash twice and the receiver's acknowledge LED should then flash on and off at a one-second rate until S3 on the receiver is released. This one-second flashing is an indication that the registration process has been successful.

If the LED does not flash, then registration was unsuccessful, so try again. Release S3 on the transmitter and receiver, then press and hold S3 on the receiver again and momentarily press S3 on the transmitter.

If the registration process still fails, try re-randomising the parameters and then register again.

The randomisation and registering procedure must be done for each new transmitter. Note that registering a transmitter will prevent the use of a previously registered transmitter if it has the same identity. For this reason, transmitters need to have their own identity. A different identity transmitter can be registered with the receiver without affecting the registration of the other transmitter.

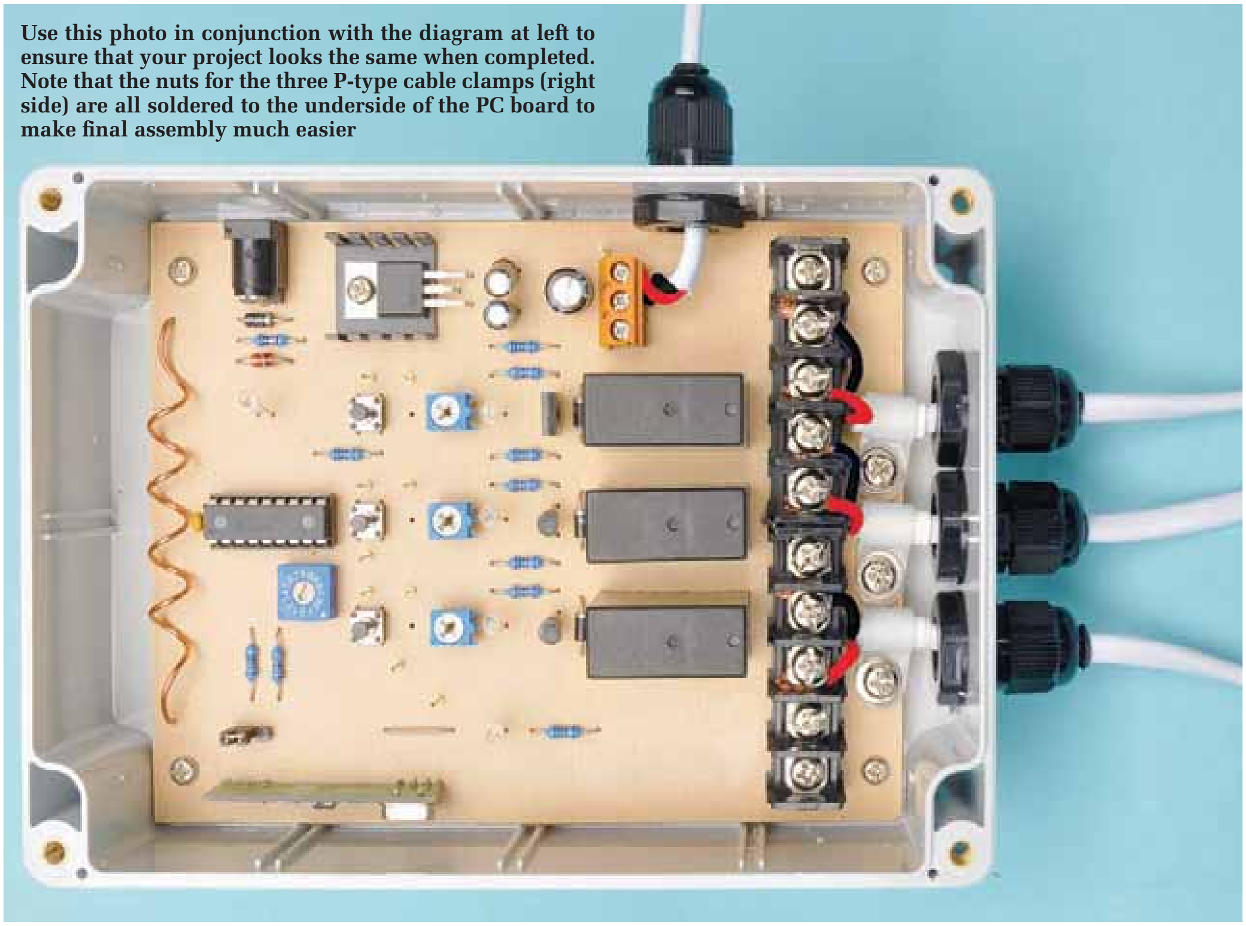
Testing transmission

If registration was successful, the LK2 jumper can be removed from the transmitter and placed in the keeper position. Switch S3 on the receiver should by now be released. The receiver is now ready to respond to the transmitter on the second press of one of the transmitter switch buttons. Pressing a switch on the transmitter for the second time should activate the corresponding relay on the receiver. It should activate the relay on each successive press of a switch thereafter.

Lockout

Any transmitter that has been synchronised can be later locked out from operating the receiver. To do this, insert link LK1 on the receiver in its 'in' position. Then set BCD1 to the identity number of the transmitter you wish to lockout. Note again that the A, B, C, D, E and F positions on BCD1 are the 10, 11, 12, 13, 14 and 15 identities. Press S1 and the acknowledge LED will light once for one second. Then it will flash briefly for about 0.25s a number of flashes equal to the identity number.

For identity 0, only the one-second flash will not occur because the identity is zero and so does not briefly



Use this photo in conjunction with the diagram at left to ensure that your project looks the same when completed. Note that the nuts for the three P-type cable clamps (right side) are all soldered to the underside of the PC board to make final assembly much easier

flash. Put another way, for identity 0, the LED does flash but for zero times. After flashing the identity number, the LED will remain off for three seconds. If switch S1 is held pressed, the cycle of displaying a one-second flash and then the identity number will occur again. This cycle will occur only for three times, as S1 is kept held pressed. After this, if S1 is still held pressed, the LED will then stay lit. This 'stay lit' indication means that now all identities are locked out.

When all identities are locked out, re-registration will be necessary for each transmitter that is in use.

Transmitter case

Switch caps supplied with the 'keyfob' transmitter case are designed to fit over the switch actuators of S1 to S3. You may find that when the lid of the keyfob case is in place, the switches are already pressed. Note also that IC1 must be pressed fully into its socket so that S1 can be operated.

The top of each switch actuator may need to be shortened by a very small amount so the switch is not depressed when the lid is in place. Take care with filing down the actuator so you do not remove too much. If you do remove too much, the switch will not work, as the switch cap will touch the switch body before the actuator is pressed. To solve this, the bottom of the switch cap can be filed to prevent it touching the switch body.

A translucent light pipe diffuser is supplied with the case, and is inserted into the hole in the top of the lid. The rounded triangular wire for a keyring attachment is placed in the case lid at the battery end of the case. A self-tapping screw holds the lid secure at the battery end of the case.

To open the case, remove the self-tapping screw and take off the battery cover compartment by prising at the holes where the keyring attaches. The lower half of the case is removed by squeezing the sides of the top half of the case to release the catches from the base.

Receiver in its box

Using Fig.6 as a guide, mark out and drill the holes in the side of the box for the four cable glands and the power lead connector. At this stage, you can also drill the holes for the four cable glands, but don't put any wire in yet.

The PC board is secured in the box using the integral corner pillars. These accept M3 x 10mm screws.

While the three on-board switches will generally not be needed once setup is finished, some constructors may wish to fit external switches, so that the relays can be activated without the keyfob transmitter (ie, a 'local' mode). In fact, external switches can completely replace the on-board switches.

In this case, momentary push-to-close switches can be installed onto the lid or side of the case and wired as shown

Table 2: Momentary period settings

Momentary period settings for VR1, VR2 and VR3 with voltages as measured at TP1, TP2 and TP3 respectively. Timeout periods are adjustable in 0.26s increments to 2s, then in 1s increments from 5 to 10s. Adjustments in 5s increments are made above 10s. Not all available timeout periods are shown in the table. You would need to interpolate the values for other timeouts. For example, to set for 2.5 minutes adjust the trimpot to between 2.79V (2 minutes) and 4V (3 minutes). A 3.4V setting should be close enough for 2.5 minutes timeout.

TESTPOINT VOLTAGE (V)	TIMEOUT
0 to 0.18	0.26s
0.26	0.52s
0.34	0.78s
0.41	1.04s
0.49	1.3s
0.57	1.56s
0.65	1.82s
0.73	2.0s
0.81	3s
0.88	4s
0.97	5s
1.36	10s
1.44	15s
1.68	30s
1.92	45s
2.15	60s
2.47	90s
2.79	2 minutes
4	3 minutes
5	4.4 minutes

in Fig.7 to TPS1, TPS2, TPS3 and GND PC stakes. A suitable switch is the Jaycar SP-0702.

If you decide not to install S1, S2 and S3 on the PC board because you are placing switches on the lid, note that the ground track on the PC board is connected via the lower two bridging terminals of switch S1. Removing S1 will mean you need to place a horizontal wire link between the lower two horizontal holes left after removing the switch. Switches S2 and S3 positions do not require any links. A note to this effect concerning S1 is located on the underside of the PC board.

Wiring into equipment

For an electric door strike, which is usually rated at less than 1A, you can use CON3 to directly drive the strike with 12V. The wires pass through a cable gland in the side of the box.

The relays are provided for switching 230V AC mains to power lights, door motors etc. The relays do not supply any power – they can simply be regarded as a switch. If controlling a light, for example, the pair of wires from each relay (common and NO (normal open)) are simply wired across the light switch. For two-way light switching, the common, NO and NC (normal closed) contacts would need to be used. These three contacts are available for outputs from Relay 1 and Relay 2.

If you want to control a garage door, you would wire across the pushbutton switch 'local' door control switch, Fig.8 shows how this is done. The pushbutton switch almost invariably controls a low-voltage circuit (hence you can use bell-push switches) so this can be run using light-duty figure-8 cable.

If using this mode, make sure the system is set for momentary operation – garage door controller local switches are almost invariably wired as push-to-open, push again to close. And some controllers might not like a long-term short across their local switch!

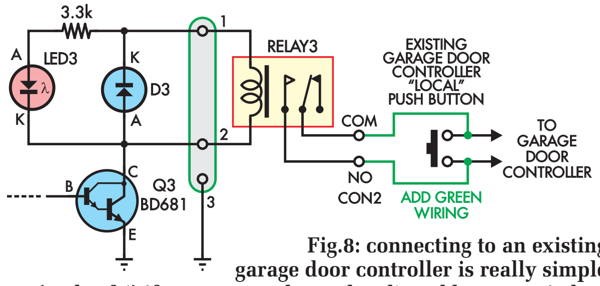


Fig.8: connecting to an existing garage door controller is really simple (and safe!) if your system has a 'local' pushbutton switch to open and close the door. This section of the circuit shows relay 3, but any of the three relays could be used – wire in the COM and NO terminals. Note that this would require the Rolling Code Remote Control to be used in 'momentary' mode

Switching mains

For switching 230V mains, the wire must be sheathed 2-core or 3-core mains flex (depending on what you are switching), rated at 7.5A 230V AC. Use 10A wire if switching more than 7.5A. The wire is passed through a cable gland in the box end and secured using a P-clamp that is attached to the PC board with an M4 × 10mm screw washer and nut.

We soldered the M4 nuts to the underside of the PC board. This allows securing the P-clamps in position without accessing the underside of the PC board. If the 2-core wire is not held tightly enough in the P-clamp, enlarge the diameter of the wire by placing a short length of heat shrink tubing over the wire. Use a second layer of heatshrink tubing, if one layer is insufficient. The cable gland also helps secure the wire when tightened.

After wiring, replace the plastic cover over the CON1/CON2 terminal strip. It snaps into place when the PC board is mounted in the case (otherwise it slides in from the side).

Disable existing controllers?

While this controller should operate quite happily in conjunction (parallel) with an existing wireless garage door controller, it could become confusing to the operators. Because you can add up to 16 transmitter remotes, you're not likely to need the old unit anyway.

We suggest disabling the existing wireless receiver. The best way to do this would be to disconnect power to the receiver without disconnecting power to the controller itself. However, in many commercial garage door openers, the receiver and door control circuitry are combined so this might prove difficult.

Because of the variety of commercial garage door controllers, we cannot offer any real advice in this area – except to say that it might be as simple as removing the external (wire) antenna which most have fitted.

This should make the existing receiver 'deaf' enough so that nothing happens if an old transmitter button is pressed!

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Errata from Part 1 of this project (August 2011)

On page 35, discussing the BCD switch, should read: Position 15 (or F) sets all switch outputs at 0V.

Frequently Asked Questions

Q. What happens if the transmitter is out of range and one of the transmit switches is pressed? Will the receiver still work when the transmitter is later brought within range and the button pressed again?

These questions are asked because the receiver was expecting a code that has already been sent and the transmitter has rolled over to a new code. So how does the system get around this problem?

A. The answer to this is that if the signal format is correct but the code is incorrect, the receiver then calculates the next code that it would expect and checks this against the received code. If the code is now correct, the receiver will operate.

If the code is still incorrect, the receiver calculates the next expected code and will do this up to 100 times. If none of these are correct, the receiver keeps its original code and it will not trigger. So the transmitter buttons can be pressed up to 100 times while out of the receiver's range without problems.

Q. How do you restore the transmitter operation?

A. The only way to trigger the receiver after this is to re-register the receiver with the transmitter. A different registered transmitter will still operate the receiver. That's because this transmitter has a different identity and a different code to the other transmitter.

Automatic Re-registration

Some rolling code transmitters systems offer automatic registration if the transmitter and receiver lose their synchronisation.

In these systems, the receiver includes a code 'look-ahead' feature, as described above, but the number of look-ahead codes is usually limited to fewer than 100. What happens is that if the code is not recognised after all the look-ahead calculations have been made, the receiver changes its synchronisation method.

Basically, the receiver requires two separate transmission codes before restoring correct operation. On the first transmission, it calculates the next code it should receive using this received code as the basis for calculation. If the second code sent by the transmitter is the same as the code that was calculated, the receiver operates.

The drawback of this latter scheme is somewhat less security, since, in theory, two successive transmission codes could be intercepted and recorded. These codes could then be re-transmitted in sequence to re-register and thus trigger the receiver.

Q. How does the receiver know which code to expect from the transmitter, since this changes each time?

A. The answer to this is that the transmitter and the receiver both use the same calculation to determine the next code. They also both use the same variables in the calculation and these variables tend to be unique values that no other transmitter uses.

For example, if the calculation for consecutive codes requires the original calculated code to be multiplied by 100 and the number 7 added to it, then both the transmitter and receiver will use these numbers to perform the calculation. The values quoted for the multiplier and increment value are not as simple as 100 and 7, but are 24 bits and eight bits respectively in length. Without knowing both the multiplier and the increment value, it would be very difficult to predict the next code. This is particularly true because of the very large numbers involved.

The code length is 48 bits, with as many as 2.8×10^{14} combinations.

This reduces by a factor of 100 because of the look-ahead feature to a 1 in 2.8×10^{12} chance of striking the correct code – still impossibly long odds.

Code scrambling

A further complication with the transmitted code is that the code is not necessarily sent in sequence. There are also 32 possible scrambling variations that are applied to the code and the scramble changes each time that code is transmitted.

Q. What if the rolling code calculation results in two consecutive codes that are the same and the code is intercepted and re-transmitted to open the lock?

A. This is highly improbable and our rolling code transmitter has safeguards preventing the same code appearing twice in succession. For each code calculation, a comparison is made between the current and last code. If the code is the same, the code is recalculated after an increment of the code value to ensure successive code calculations diverge. It is this new code that is transmitted.

The receiver performs the same re-calculation so that the new code will be accepted.

A warning, though, is that, as with any encoded UHF encoded transmission, the signal can be intercepted and recorded. When played back it can be used to unlock a receiver. This is particularly true of fixed code systems where the same code is always used.

For rolling code systems, a capture of the transmitted code can be used to unlock the system if the code is captured when the transmitter is used out of range from the receiver. The captured code could then be used to unlock the receiver if it is transmitted before the genuine transmitter is used to unlock the receiver. The captured code will only work once because the receiver will change to its new code upon reception of the signal. The captured signal will also be nullified if the genuine transmitter is used to unlock the receiver.

Q. Does each transmitter use the same rolling code calculation and if so, wouldn't the receiver lose its synchronisation if several transmitters were used?

A. Each transmitter is treated independently to another and uses different rolling code and calculation parameters. So a receiver will not lose synchronisation with a particular transmitter, even if it is not generally used. Imbedded in the rolling code is the transmitter identity value from 0-15 and so the receiver knows which transmitter is sending the signal. ***EPE***

Edible Computing

TechnoTalk

Mark Nelson

Forget 'grey goo' — how about computers based on 'smart yogurt'? Or perhaps you'd like to get your own back on viruses to make them perform electronic assembly tasks? Mark reports the news stories that even his addled brain couldn't make up.

PRINCE Charles hit the headlines in 2003, when he expressed his views about nanotechnology. It appears he was misquoted, since afterwards he denied having used the expression 'grey goo' or stating that he believed that self-replicating robots, smaller than viruses, would one day multiply uncontrollably and devour our planet. 'Such beliefs,' he added, 'should be left where they belong, in the realms of science fiction.'

Molecular nanotechnology has always had a slightly edgy image, as the Wikipedia article on the subject explains: **http://en.wikipedia.org/wiki/Grey_goo**. Discussion of nanomachine technology dates back to 1986, when the term 'grey goo' was first coined, and it is still a favourite of futurologists. The only difference is that scientists are now demonstrating practical prototype devices.

Molecular computing

One of the first steps towards molecular computing was revealed last year, when scientists from Michigan Technological University in the USA demonstrated a novel computer com-posed not of silicon, but of organic molecules on a gold substrate. In fact, this different kind of computer is built out of DDQ, a hexagonal molecule made of nitrogen, oxygen, chlorine and carbon that self-assembles in two layers on a gold substrate. An important difference is that the DDQ molecule can switch among four conducting states – 0, 1, 2 and 3 – unlike familiar binary switches – 0 and 1– as used by digital computers.

'Grey matter' was the inspiration for this proof-of-concept demonstration, in which evolving patterns on this molecular processor mimic patterns displayed by the human brain. Explained physicist Ranjit Pati, 'We have mimicked how neurons behave in the brain and the evolving neuron-like circuit network allows us to address many problems on the same grid, which gives the device intelligence.'

As well as intelligence, this approach to information processing also gives far greater speed. 'Modern computers are quite fast, capable of executing trillions of instructions a second, but they can't match the intelligent performance of our brain. Our neurons only fire about a thousand times per second. But I can see you, recognise you, talk with you, and hear someone walking by in the hallway almost instantaneously, a Herculean task for even the fastest computer.'

Waiting for the right technology

Interestingly, the principles of this molecular computer were first proposed as far back as 1955 by the Hungarian-American quantum mechanics spec-ialist John von Neumann. At that time, von Neumann was only able to demonstrate his 'cellular automaton' system for parallel computing on a piece of graph paper, moving black and white dots together according to simple rules.

It took another 55 years to realise this physically for the first time using molecular monolayers. It is, of course, only a conceptual breakthrough, and at a very rudimentary stage, but the possibilities of processing information so rapidly have remarkable potential.

According to Bandyopadhyay, robots could become much more intelligent and productive than today if his team's molecular computing approach is adopted. He explains: 'Current robots cannot cope with changing environments, and they will be unable to survive in more hostile environments than those they were programmed for. Their intelligence is very limited, even when compared to viruses and bacteria. With our hardware, robots can take many decisions at a time, which no computer can do. They can come up with new solutions an infinite number of times, which we can never expect from a normal robot.'

Smart yogurt

One of the most interesting proponents of new technology is futurologist Ian Pearson, who expressed his fascinating ideas on biological computing on a BBC *Radio 4* programme earlier this year. So, forget 'grey goo'; the new thing is 'smart yogurt' – linkable electronics in bacteria such as *E. coli*. I called this the new thing, but Pearson came up with the concept as long ago as 1997.

Five years ago he stated: 'You modify a real live bacterium – *E-coli* or something you find in yoghurt – so that it creates electronic circuits within its own cells. That's really good fun, because you've got electronic bacteria – a real live bacterium, which can replicate with electronics in it. The electronics have nothing to do with the bacteria, they are just there, but they turn it into 'smart bacteria' because you can then connect those electronics together using infrared or bioluminescence and make completely scalable electronic circuits'.

'So you start off with one bacterium, which is essentially a module, and you link billions of these together and you've got something that makes your PC look pretty primitive. We'll have a 'smart yoghurt' by about 2025, we did the calculations, and we reckon that it's possible to make a yoghurt with roughly the same processing power as the entire European population.'

What else could you achieve with smart yogurt? On his blog, Pearson explains: 'You can do active skin, with 10 micron chips containing hundreds of thousands of transistors embedded among skin cells, using infra-red to communicate with each other. They will analyse blood passing in capillaries. They will monitor and record nerve signals associated with sensations, and allow them to be replayed at will'.

'We will embed chips in our corneas to raster scan lasers onto our retinas to create full 3-D high-res video overlays on what we see in the real world'.

Viruses welcome here

If you feel it's high time to redress the harm and misery wrought by viruses, you'll be pleased to learn that researchers at the Massachusetts Institute of Technology (MIT) have found a way of using genetically-modified viruses in a process that improves the efficiency of solar cells by nearly one-third. A report from MIT explained that significant improvements can be made to the power-conversion efficiency of solar cells by enlisting the services of tiny viruses to perform detailed assembly work at the microscopic level.

In this new development, researchers found that a genetically-engineered version of a virus called M13, which normally infects bacteria, can be used to control the arrangement of the nanotubes on a surface. It keeps the tubes separate so they can't short out the circuits, and separates the tubes so they don't clump. The two functions are carried out in succession by the same virus, whose activity is 'switched' from one function to the next by changing the acidity of its environment. Whatever next?

Auto-dim add-on for the 6-Digit GPS Clock

By JIM ROWE

Here's a low-cost add-on for the Digital GPS Time Display published in our May and June 2011 issues. It senses the ambient light level, so that a modified program running in the display unit's PIC controller can adjust the LED brightness to a comfortable level – ranging from full brightness when the ambient light level is high, down to dim when the ambient light is very low.

SOON after the basic *6-Digit GPS Time Display* was published in the May 2011 issue, we received emails from readers who were disappointed that we hadn't provided the design with an 'autodim' facility. And they wanted to know if such a feature could be added in.

Unfortunately, trying to incorporate dimming on the existing clock PC board is quite difficult. The conventional way of doing it would be to use a transistor and LDR circuit to control the emitters of all six common-cathode driver transistors, Q15 to Q20. We have used this scheme on quite a few past projects which had a PIC micro and 7-segment LED displays, but a quick look at the PC board pattern shows that it would be quite impractical.

This presented a real dilemma until we came up with an alternative scheme: use an LDR and transistor circuit to allow the PIC micro to directly monitor the ambient light level, and then change the duty cycle of the multiplexed drive to the 7-segment displays.

So we set out to develop the *Auto-dim Display Sensor* described here. The hardware was the easy bit, of course – the firmware mods took a bit longer.

How it works

The new hardware consists of just a few parts on a small PC board. This mounts on 10mm spacers in front of the display unit's main PC board, in place of the DB-9 connector (CON1) which was originally used to feed in the NMEA-0183 data stream from the GPS frequency reference.

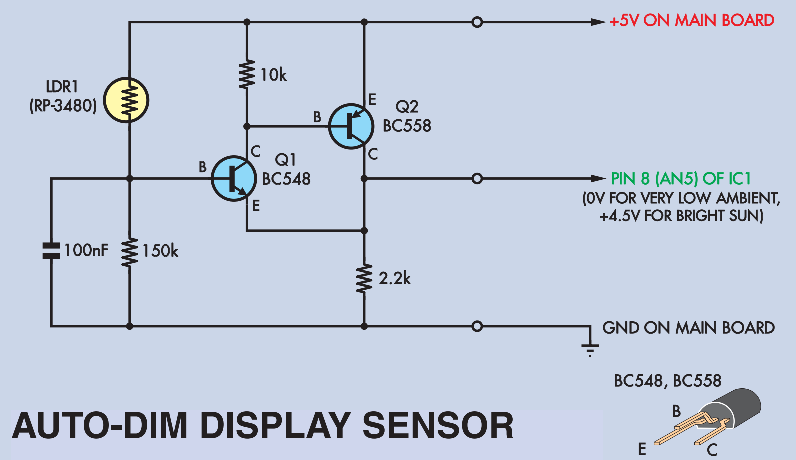


Fig.1: the circuit uses an LDR to sense the ambient light level. The resulting DC voltage across the 150kΩ resistor is then buffered by complementary emitter follower stage Q1 and Q2, and fed to pin 8 of the microcontroller on the display board.

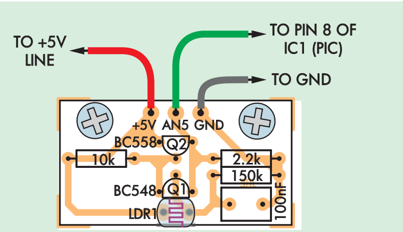


Fig.2: install the parts on the PC board as shown here. Take care not to get the two transistors mixed up.

The DB-9 connector (CON1) is no longer needed if you're using the GPS receiver module described in the June 2011 issue.

Fig.1 shows the circuit details. The ambient light level is sensed by LDR1, a small light-dependent resistor (LDR) which varies its resistance between about 2MΩ in the 'dark' and a couple of hundred ohms in bright sunlight. This LDR is connected in series with a 150kΩ resistor across the +5V supply. As a result, resistance changes in the LDR result in corresponding DC voltage changes across the 150kΩ resistor, the level varying from close to 0V when the ambient light level is very low, up to about +4.5V in bright sunlight.

Unity-gain buffer

The other components in the circuit, based on transistors Q1 and Q2, make up a near-unity gain impedance step-down buffer. This ensures that the light-dependent output voltage is made available at a much lower impedance level than 150kΩ.

In greater detail, transistors Q1 and Q2 form a complementary emitter follower, with a source resistance much lower than the 2.2kΩ emitter/collector resistor. This makes it suitable for driving one of the analogue-to-digital converter (ADC) inputs of the display's PIC18F877A microcontroller (IC1). In this case, the sensor voltage is fed to the micro's AN5 ADC input.

That's really all there is to the hardware side of the add-on, apart from the 100nF capacitor across the 150kΩ resistor. This capacitor is used to filter the LDR's output voltage, to remove any modulation from the indoor ambient lighting level.

Modified firmware

The modified firmware for the PIC regularly monitors the voltage applied to the AN5 input (pin 8). It does this by directing the ADC module inside the PIC to measure this voltage. It then tests the measured voltage level and varies the on-off ratio of the display digit switching signals to vary the apparent display brightness, over six levels.

As a result, the apparent display brightness varies between virtually full brightness at high ambient light levels, down to about 17% of full brightness at very low ambient levels.

Building it

As mentioned earlier, the additional components are all mounted on a small PC board. This is coded 819 and measures just 36mm × 19mm. This board is available from the *EPE PCB Service*.

Fig.2 shows the parts layout on the PC board. The only polarised components are transistors Q1 and Q2, so make sure you fit these with the orientation shown. Also, be careful not to swap the two: **Q1 must be an NPN BC548, while Q2 is a PNP BC558.**

The LDR is not polarised and can be fitted either way around. Leave its leads about 15mm long so that they can be bent outwards from the PC board

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	150kΩ	brown green yellow brown	brown green black orange brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	2.2kΩ	red red red brown	red red black brown brown

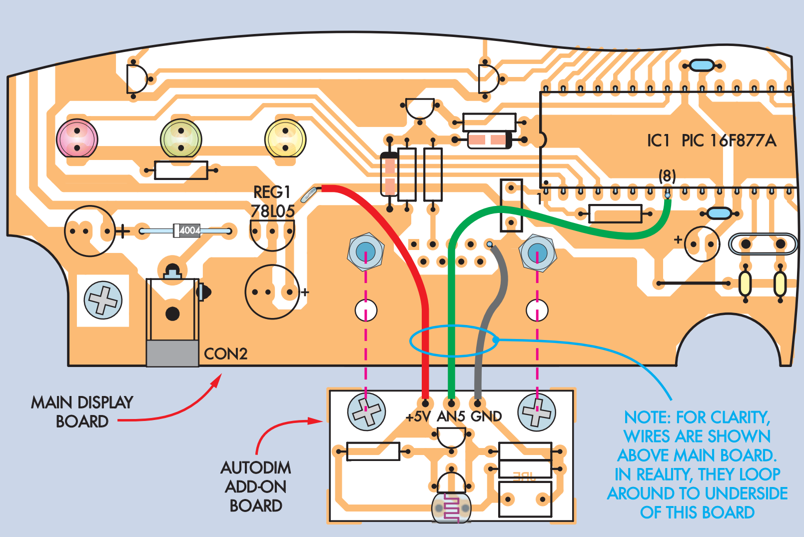
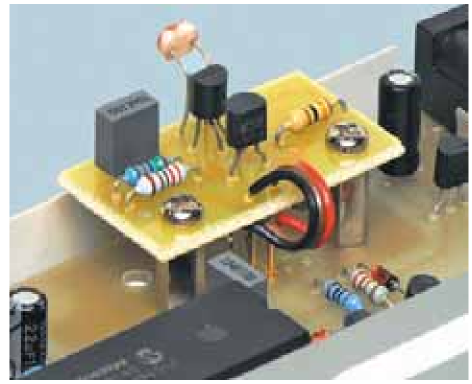


Fig.3: only three leads are required to connect the auto-dim board. Note that the connections are actually run to the *underside* of the display board.



The auto-dim board is mounted on two M3 × 10mm tapped spacers. These are attached to the main board using the holes originally provided to secure the DB-9 connector (CON1).

after it is fitted to the board. This allows the sensitive 'front face' of the LDR to be turned away from the main LED displays when the add-on board is mounted in position.

Note: if the LDR is able to pick up too much light from the displays themselves, the auto-dimming feature won't work. Instead, the displays will run at full brightness, regardless of the ambient light level.

Only three wires are required to connect the auto-dimming board to the main display board. Fig.3 shows the details.

The first step is to solder three 80mm lengths of light-duty hookup wire to the three external wiring points (ie, +5V, AN5 and GND). That done, attach two M3 × 10mm tapped spacers to the underside of the add-on board, using two M3 × 6mm machine screws.

Board mounting

The completed add-on assembly can now be mounted in the lower left-hand corner on the main display board. You will have to remove the display board from its case in order to do this. The add-on board is secured in place using two further M3 × 6mm screws, which pass up through the upper pair of 3mm holes that were originally provided to secure the DB-9 connector (CON1) – see photos.

Parts List

- 1 PC board, code 819 available from the *EPE PCB Service* 36mm × 19mm
- 2 M3 × 10mm tapped spacers
- 4 M3 × 6mm machine screws
- 1 light dependant resistor (LDR1)
- 3 80mm lengths of light-duty hookup wire

Semiconductors
- 1 BC548 *NPN* transistor (Q1)
- 1 BC558 *PNP* transistor (Q2)

Capacitors
- 1 100nF MKT metallised polyester

Resistors (0.25W 1%)
- 1 150kΩ
- 1 2.2kΩ
- 1 10kΩ

The three leads from the add-on board can now be fed to the rear of the main board and connected to the appropriate points underneath. As shown in Fig.3, the +5V lead goes to the +5V supply rail near the output pin of REG1, while the ground wire goes to the earth copper at what was originally pin 5 of CON1.

The third centre wire (AN5) goes to pin 8 of the display's PIC16F877A micro (IC1). This pin was not used in the original 'non-dimming' version.

Once these three connections have been made, you can slip the finished board assembly back into the enclosure and fasten it in place. All that now remains is to download the new version of the GPS Time Display firmware from the *EPE* website (**www.epemag.com**) and reprogram the PIC micro so that it knows how to monitor the LDR voltage and vary the display brightness accordingly.

Note that the add-on board by itself won't give you the auto-dimming function unless you use the revised firmware in your PIC.

The updated firmware now replaces the original program, whether or not you have the add-on board. **However, if you don't have the add-on board, you must now connect pin 8 of IC1 to the adjacent +5V supply rail via a 2.2kΩ resistor.**

This is necessary to give the PIC's AN5 input a *de facto* 'bright sun' input voltage level in the absence of the LDR sensor board.

That's it! With the add-on LDR sensor board and the modified firmware running inside the PIC, your GPS Time Display will now be able to adjust its brightness according to the ambient light level. ***EPE***

EPE EXCLUSIVE

Win a Microchip Accessory Development Starter Kit For Android

EVERYDAY PRACTICAL ELECTRONICS is offering you the chance to win a Microchip Accessory Development Starter Kit for Android (DM240415), enabling accessory development for Google's Android platform. The Microchip PIC24F Accessory Development Start Kit for Android is a standalone board used for evaluating and developing electronic accessories for Google's Android operating system for smartphones and tablets.

Specifically, Android versions 2.3.4 and 3.1 and later include a new framework that allows apps to communicate directly with an accessory connected to a smartphone or tablet, via USB. The kits consist of a development board and a software library, available via free download from: **www.microchip.com/get/522D**, which enable the fast and easy development of Android smartphone and tablet accessories based on Microchip's large portfolio of 16-bit and 32-bit PIC microcontrollers.

This starter kit bundles five major components, including 16-bit PIC24F Development Board, PICkit 3 In-Circuit Debugger (PG164130), RJ-11 to ICSP Adapter (AC164110), 9V Power Supply (AC002014) and royalty-free, no-fee licensed software library.

Microchip's starter kits make it easy for designers to quickly design, develop and debug electronic accessories for this large and growing market. In addition to providing the schematics and gerber files for the development boards, the free software library includes a sample application protocol and an abstraction layer, which enables designers to focus on creating the application.

The development boards feature a USB connector, an on-board debugger, a programming user interface and standard Arduino connectors, for use with a host of third-party 'Shield' expansion daughter cards.

Example accessory applications include: automotive (car kits, audio, GPS); home (audio docks, remote controls, data backup); fitness/health (glucose meters, fitness equipment); and business (credit-card terminals, projectors).

HOW TO ENTER

For your chance to win a Microchip Accessory Development Starter Kit for Android, visit:
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CLOSING DATE

The closing date for this offer is 31 October 2011

Recycle It!

BY JULIAN EDGAR
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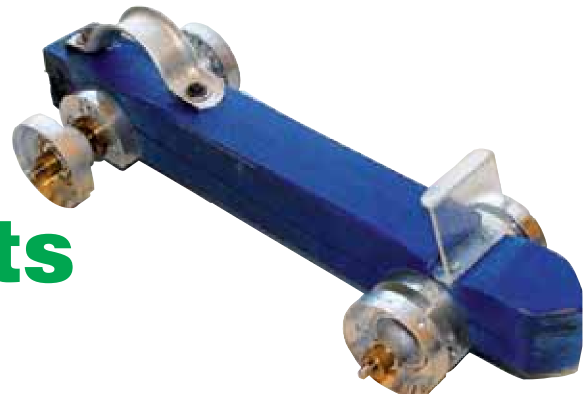
Fun Projects From Salavaged Parts



IF YOU keep your eyes open, it's easy to salvage from other people's discards a whole range of interesting parts and devices. Here are six that I've recently been playing with.

Music player

THE other day, when pulling apart a PC, I spotted this stereo, amplified speaker system. It was slotted-into the rack under a disc drive. It is normally powered by the PC and comes complete with a ¼-inch stereo plug on a cord. On the front is an 'on' LED and a volume control.

Having been after a lightweight music player to work with my iPhone, I wondered if it could be easily adapted to suit. Despite being powered from the 12V rail of the PC, I soon found that it was happy working down to 3V. I opened-up the box and found space for two AA cells and then I added an on/off switch (like the battery holder, a salvaged part).

The result is surprisingly good – certainly not hi-fi, but quite acceptable in quality and volume as a lightweight (280 grams!), portable music player that will work with any MP3 unit.

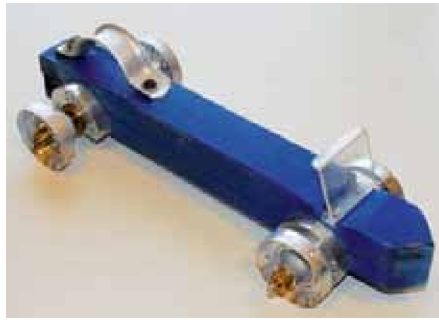
Unbreakable mirror

TALKING about light-weight items, have you checked-out the platters inside a PC hard disc drive? Current ones are glass or ceramic (not so useful), but older ones of the sort you can pick up for nothing are aluminium. The discs are very thin and about 95mm in diameter. They're coated in a material able to be magnetised and then highly polished. And it's this mirror polish that makes them interesting.

As someone who goes camping (normally via a pedal machine), I am amazed at how effective a hard drive platter is as a light-weight (just 15 grams!), indestructible mirror. A platter is perfect as a personal mirror and, more importantly, as an emergency signalling mirror. The hole through the middle even allows you to see exactly where the reflected light is going. Signal mirrors are generally regarded as having about a 15km range – that's an awful lot further than your shouting will be heard!

Unbreakable, ultra light-weight – and free!

Land speed record car toy



MY five year old son is fascinated by land speed record cars, and wanted to make his own. However, it had to be fast on carpet (not a criterion that applies to the full-size cars!).

This is the result of our construction – and it's relevant here because of the wheels and bearings. The 'body' of the toy is just a piece of shaped timber. The windscreen is made from a cut-down cassette deck door and the rear wing/spoiler/handle is half of an industrial clamp.

All four wheels, bearings and mounts are made from video drums salvaged from VCRs. Because of slight differences in construction of the video drums, all four wheel assemblies vary a little in appearance – but that doesn't matter.

On the carpet, the toy is fast and tracks beautifully – after all, each wheel is equipped with a hardened steel axle and two precision sealed ball bearings! And, perhaps oddly enough, like this toy, many land speed record cars do actually use solid metal wheels.

It's also interesting that in this age of mass-produced and very cheap toys, this homebuilt car has continued to be treasured for months after it was first built, and in fact has even made a trip to school as part of a 'show and tell' session. 'What's it made from?' the other children asked Alexander. 'It's made from recycled stuff from the rubbish tip!' was his proud reply. In fact, all that was bought new was the paint.

Pressure switch

INSIDE any older washing machine you'll find a very sensitive pressure switch – good salvage material. But often, when you need a pressure switch, the washing machine items are both too large and too sensitive. But that's no problem, just pick up a spa bath at the local rubbish tip! Pardon? Well, you don't actually need to collect the whole bath – just some of its electricals.

Most spa baths use pneumatic switching to control their operation. A non-electrical pushbutton (basically, just a simple pneumatic plunger), is connected by plastic tubing to a pressure-operated microswitch. So, when you're sitting in the spa and press the button, you develop air pressure in the tube that triggers the remote microswitch. Pull out the electrical switch and you have a small, self-contained, momentary pressure switch, normally rated to mains voltages, that triggers at about 1psi.

You can, of course, use it in the same way as its maker intended – switching mains power when in dangerously wet conditions. Or you can use it as a pure pressure switch. For example, in car applications where the engine uses forced aspiration (that is, either a turbo or supercharger), the pressure switch can be used to trigger something when the engine is on boost. The 'something' could be as simple as a dashboard indicator, or as complex as an intercooler water spray.

Ultra high-pressure pump

YOU don't come across them often as thrown away items – but with their current popularity, that's sure to change. So what am I talking about? Those expensive home cappuccino machines, that's what!

The interesting thing about these machines is that they contain a high pressure water pump, for example rated at a maximum pressure of 15 bar (over 200psi!). The pump contains a coil, an internal piston and a one-way valve. When the coil is connected to mains AC current, the piston oscillates at mains frequency, producing a pulsating flow of water. If the outlet is restricted, the flow rapidly builds to a high pressure.

If you need a finely atomised water spray, one of these pumps and a good quality brass misting nozzle will produce an extraordinarily fine droplet size. So for humidifying or spray-water cooling, these pumps are amazing. Note that the pumps are designed for intermittent use, so if you are running one for longer than (say) a minute at a time, add fan cooling and monitor the pump's temperature.

Magic flasher

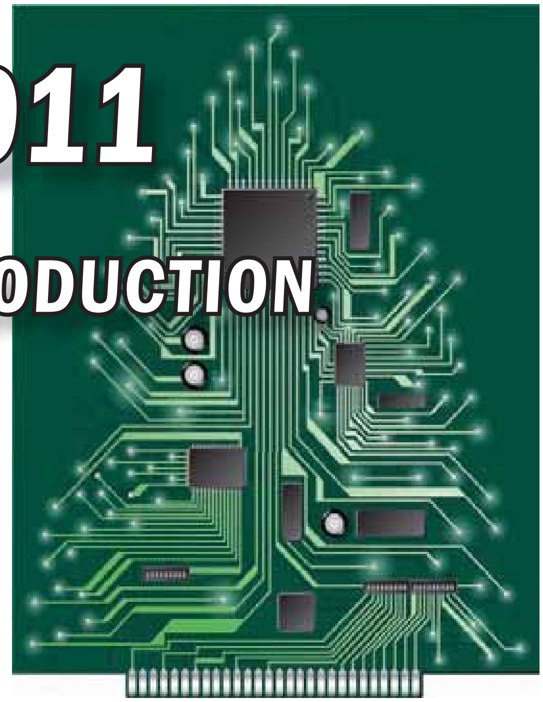
HERE's a fascinating – but very simple – device to make.

It uses the solenoid salvaged from a hair or beard trimmer, an LED (I used a 10mm high intensity LED) and one of the two powerful magnets from a microwave oven's magnetron. **(If salvaging from a microwave oven, you need to be extremely careful of the high voltage capacitor that can give a lethal bite – don't delve inside microwaves unless you know exactly what you are doing.)**

So what happens? Hang the magnet from a long piece of string or flexible wire, and then place it where there is space for the magnet to swing back and forth like a pendulum. Connect the solenoid directly to the LED and then locate the solenoid so that its pole piece is positioned directly beneath the hanging magnet. When the magnet swings past, it should clear the solenoid armature by only a millimetre or two.

Pull the magnet back and let is swing past the solenoid. Each time it whizzes past, the LED will give out a bright flash, especially effective in a semi-darkened room.

Of course, the electricity to light the LED is generated by the movement of the magnet past the solenoid coil – but to most people, it looks like magic. They wonder what makes the LED light as the magnet goes by. If you set the scene by saying some mumbo jumbo about the 'mysterious' process, people will come up with all sorts of theories as to why the LED lights. They'll ask – but where are the batteries? And how does the coil 'know' the magnet is nearby? (One person said: 'There's a reed switch inside the coil!'.) Simple fun – and, of course, you can take the same idea and with a few more salvaged parts, make a hand-cranked high intensity LED flasher.



TEACH-IN 2011

A BROAD-BASED INTRODUCTION TO ELECTRONICS

Part 11: Summing it all up

By Mike and Richard Tooley

Our Teach-In series is designed to provide you with a broad-based introduction to electronics. We have attempted to provide coverage of three of the most important electronics units that are currently studied in many schools and colleges in the UK. These include Edexcel BTEC Level 2 awards, as well as electronics units of the new Diploma in Engineering (also at Level 2). The series will also provide the more experienced reader with an opportunity to 'brush up' on specific topics with which he or she may be less familiar.

Each part of our Teach-In series is organised under five main headings; Learn, Check, Build, Investigate and Amaze. Learn will teach you the theory, Check will help you to check your understanding, and Build will give you an opportunity to build and test simple electronic circuits. Investigate will provide you with a challenge which will allow you to further extend your learning, and finally, Amaze will show you the 'wow factor'!

IN THIS instalment of *Teach-In 2011*, we bring our series to a conclusion with a quick review of the previous ten parts, and include a comprehensive index that will help you to locate the key topics that we've introduced as the series has progressed. There's also a selection of questions and fun activities, including a crossword, that will help you to check your understanding.

For good measure, we've also included eight additional circuits for you to investigate using the Circuit Wizard software.

Learn

Looking back

We began our Teach-In series by looking at the signals that are used to convey information in electronic circuits. We discussed the units and quantities that we use when making measurements in electronic circuits, and how waveforms are used to show how the voltage and current in an electronic circuit vary with time. We also introduced batteries and power supplies that we use to provide power to electronic circuits.

Part 2 dealt with resistors, capacitors, timing circuits and Ohm's Law. We also found out what happens when a capacitor is charged or discharged.

Part 3 provided you with an introduction to diodes and power supplies. We investigated the voltage/current characteristics for two different types of diode, and showed how they could be used together with a transformer to produce a power supply. We also looked at light emitting diodes (LEDs) and Zener diodes.

Transistors were the subject of Part 4. We described the operation of *NPN* and *PNP* transistors, and explained how they are used to amplify current and operate as saturated switches.

An introduction to operational amplifiers (op amps) was the subject of Part 5. We showed how operational amplifiers can be connected in *inverting*, *non-inverting* and *differential* arrangements, as well as showing how they could be used as comparators, where one voltage is compared with another.

Logic circuits were explained in Part 6. Here we met the symbols, truth tables and Boolean logic for each of the most common types of logic gate. We also introduced bistable devices, and showed how they could be used in binary counters. The highly versatile electronic timer (555/6) was introduced in Part 7. These versatile circuits can be used to produce accurate time delays and repetitive pulse waveforms.

Analogue circuit applications, in the form of attenuators and filters, were described in Part 8. We explained the characteristics of low-pass, high-pass and band-pass filters and showed how these could be built using simple arrangements of resistors, capacitors and inductors. We also introduced some simple active

Crossword Check – How do you think you are doing?

The month's Check panels provides you with an opportunity to test your understanding of the previous ten parts of our *Teach-In 2011* series.

The first question tests your knowledge of some of the terms that are commonly used in electronics

11.1. Solve the crossword shown in Fig.11.1.

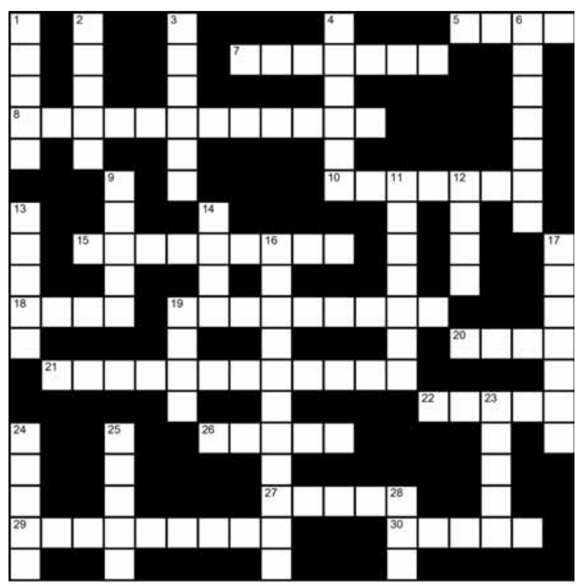


Fig.11.1. Common terms used in electronics

Clues across

5 Amplitude (4)
7 Instrument for measuring current (7)
8 Polarised capacitor (12)
10 Commonly used for logarithmic ratios (7)
15 Most positive connection of an *NPN* transistor (9)
18 Very common type of waveform (4)
19 Stores electric charge (9)
20 Unit of potential difference (4)
21 Instrument used to display waveforms (12)
22 P in PRF (5)
26 Most positive connection on a conducting diode (5)
27 ×0.000001 (5)
29 Peak or maximum value (9)
30 Unit of frequency (5)

Clues down

1 Used to produce delays (5)
2 Diode voltage reference (5)
3 Present on the plates of a capacitor (6)
4 Time for one cycle (6)
6 Circuit that has no stable state (form of oscillator) (7)
9 Allows current to flow in one direction only (5)
11 C in CRT (7)
12 Input of a common-emitter amplifier (4)
13 Fast analogue-to-digital converter (5)
14 ×1,000,000 (4)
16 Steps alternating voltage up or down (11)
17 Most positive connection of a *PNP* transistor (7)
19 Smallest indivisible part of a battery (4)
23 L in LED (5)
24 Unit of capacitance (5)
25 ×0.001 (5)
28 Unit of resistance (3)

Crossword solution – page 53

filters based on op amps. For good measure, we explained how decibels are used to express gain or loss in electronic circuits.

In Part 9, we showed how an analogue signal can be converted to digital data, and *vice versa*. We described the process of quantisation and explained how the number of data bits affects the accuracy and resolution of a DAC and ADC.

Part 10 dealt with the practical aspects of constructing and testing electronic circuits. We introduced some basic items of test equipment in the form of *multimeters* and *oscilloscopes*, and showed how these could be used to measure voltage, current, frequency, time and waveform in an electronic circuit.

Check – How do you think you are doing?

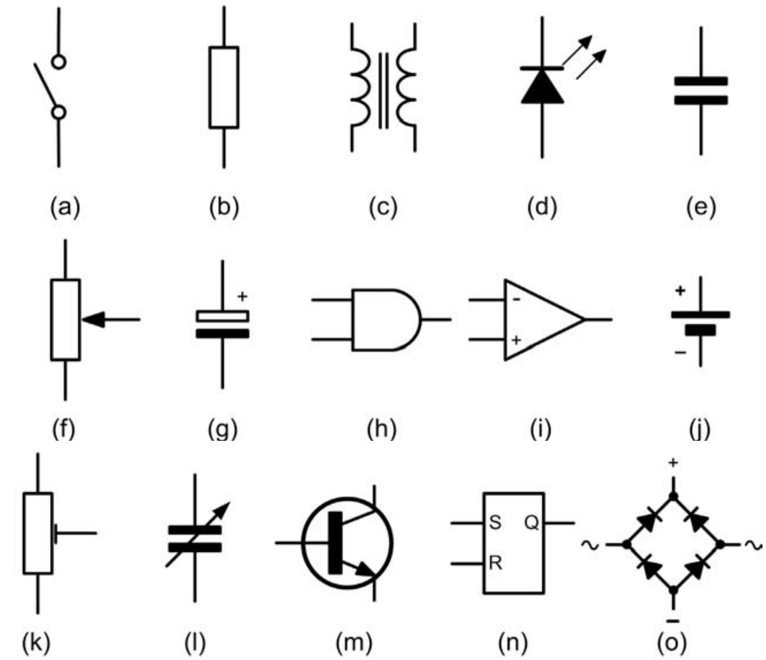


Fig.11.2 See Question 11.2

The next question tests your ability to recognise the symbols used in circuit diagrams:

11.2. Identify each of the symbols shown in Fig.11.2.

Question11.3 and Question 11.4 test your ability to extract information from a waveform:

11.3. For the waveform shown in Fig.11.3(a):

(a) What type of waveform is shown?

(b) What is the frequency of the waveform?

(c) What is the periodic time of the waveform?

(d) What is the amplitude (peak value) of the waveform?

11.4. For the waveform shown in Fig.11.3(b):

(a) What type of waveform is shown?

(b) What is the pulse repetition frequency of the waveform?

(c) What is the periodic time of the waveform?

(d) What is the duty cycle of the waveform

(e) What is the peak-peak value of the waveform?

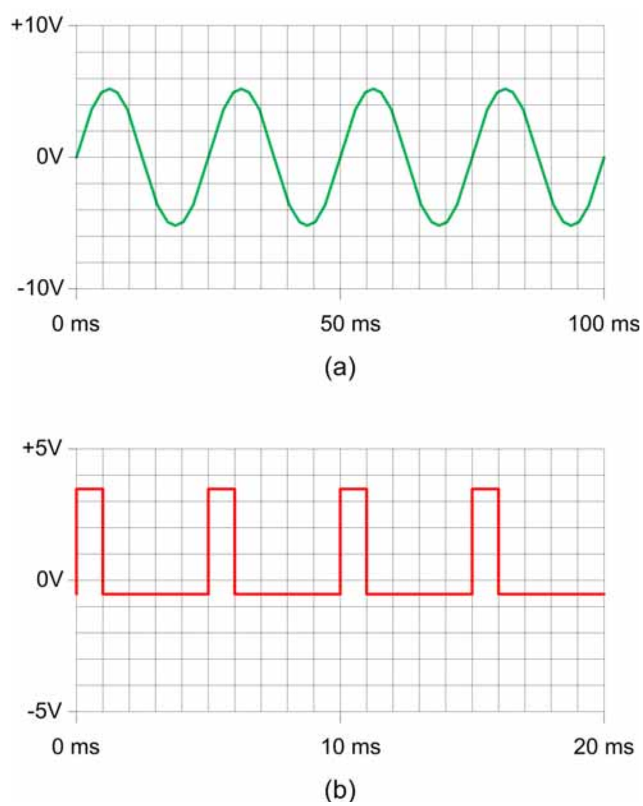


Fig.11.3 (right). See Question 11.3 and Question 11.4

The next two questions test your knowledge of some of the units and quantities used in electronics:

Quantity	*Unit*	*Abbreviation*
Electric potential	volt	
	ampere	A
Electric power		W
Capacitance		F
Resistance	ohm	
Frequency		Hz
Bit rate		Bps

11.5. Complete the table of electrical quantities and units of measurement

Definition	*Unit*
The potential that appears between two points when a current of one ampere flows in a circuit having a resistance of one ohm	
The current that flows in an electrical conductor when electric charge is being transported at the rate of one coulomb per second	
	1 watt
The resistance of a circuit when a current of one ampere flowing in it produces a potential difference of one volt	
	1 hertz

11.6. Complete the table of definitions shown above

Question 11.7 tests your ability to convert multiples and sub-multiples to fundamental units:

11.7. Express:
(a) 250mV in V
(b) 0.15mA in μA
(c) 68000Ω in kΩ
(d) 0.235W in mW
(e) 0.22MΩ in kΩ
(f) 885Hz in kHz
(g) 1500pF in nF
(h) 1.2kbps in bps

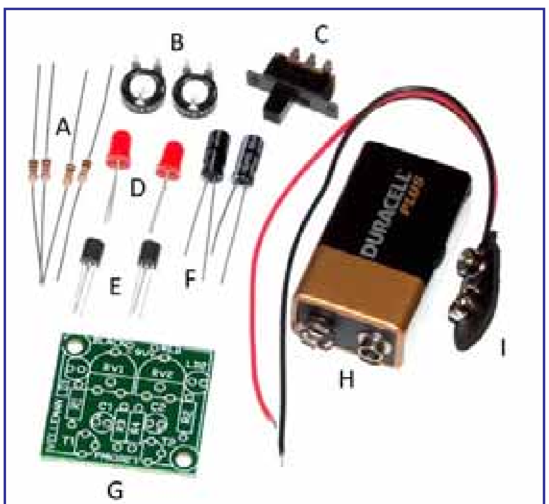


Fig.11.4. See question 11.8

The next question tests your ability to recognise some common electronic components:

11.8. Fig.11.4 shows a kit of parts needed to build a simple astable LED flasher. Identify the parts marked A to I.

Question 11.9 checks a basic understanding of basic digital logic:

11.9. Sketch logic circuits showing how:

(a) a four-input AND gate can be built using three two-input AND gates

(b) a four-input OR gate can be built using three two-input OR gates

(c) a two-input AND gate can be built from two two-input NAND gates.

(d) a two-input OR gate can be built from two two-input NOR gates.

Finally, Question 11.10 tests your ability to read and understand a simple electronic circuit diagram:

11.10. Fig.11.5 shows the circuit of a simple headphone amplifier in which all of the fixed resistors have a tolerance of ±5%.

(a) What type of component is C2?

(b) What type of component is TR3?

(c) Which two components are connected to the base of TR1?

(d) What colour code would be marked on R2?

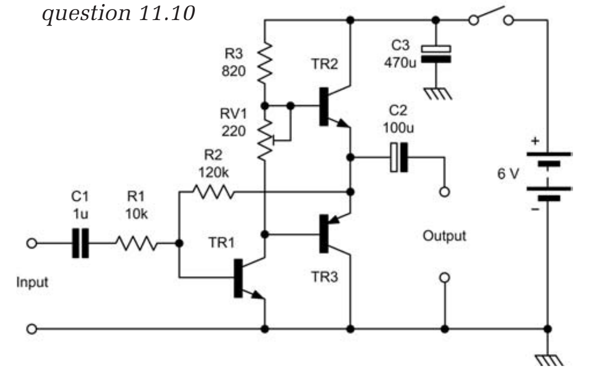
(e) Which component is adjustable?

(f) What voltage will appear across C3 when S1 is closed?

(g) If a current of 3mA flows in R3 what voltage will appear at the base of TR2?

(h) Which component provides negative feedback?

Fig.11.5. See question 11.10



The answers to these questions are shown on page 54

Build – The Circuit Wizard way

OVER the *Teach-In* series, our ***Build*** section has put theory into practice using Circuit Wizard to simulate a whole range of electronic circuits. We've shown how using simulation software is great for allowing you to really get to the bottom of how a circuit actually operates, as well as being a crucial tool for electronic designers.

In this, the last edition we are giving you the opportunity to try out your 'wizard' skills with a selection of practical circuits that you can enter and investigate. For each circuit, we've included a brief description, along with some suggestions for experimentation and a few questions to help test and extend your understanding of the underpinning theory. These circuits are a great starting point for your own projects and circuit designs.

COIN TOSS

Description

The circuit shown in Fig.11.6 uses a J-K flip-flop that is clocked at a very high speed. When switch SW1 is pressed, the flip-flop is clocked and alternates at 1kHz (that's one thousand times a second).

During this time, the LEDs will appear to flicker rapidly or may seem dimly lit. When the button is released, the flip-flop will remain in one state and hence one LED will remain lit to signify either 'heads' or 'tails'. The circuit is not truly random, but because the output is changing so quickly it would be hard to get a consistent output by timing the button press.

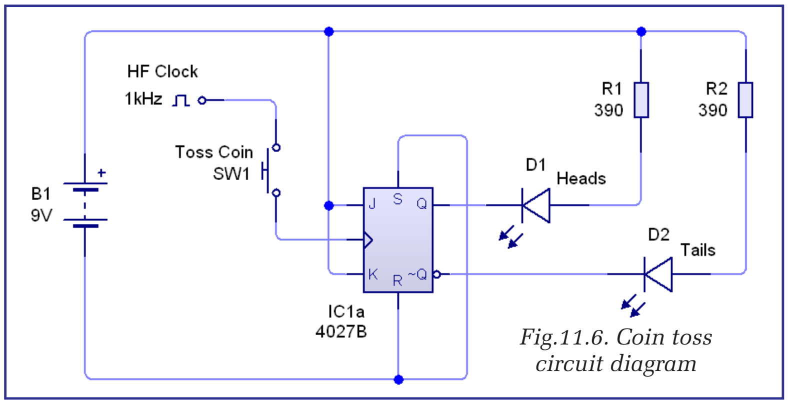


Fig.11.6. Coin toss circuit diagram

Investigate:

1. We've used the in-built clock device – try to create your own clock generator (perhaps using a 555 astable or a Schmitt oscillator circuit).

2. The coin toss circuit is not truly random – how could we generate a real random selection?

3. How could we extend the circuit to give six outputs – ie, to create an electronic dice?

EGG TIMER

Description

The egg timer circuit shown in Fig.11.7 is a classic 555 bistable circuit. Switch SW1 selects between a soft-boiled (~3 min) and hard-boiled (~5 min) egg by changing the resistor through which capacitor C1 is charged. When the circuit is powered, the buzzer (BZ1) will sound until switch SW2 is pressed to start the timer. For this reason a practical version of this circuit should include a further toggle switch to connect/disconnect the power supply.

Investigate:

1. Monitor the charge on capacitor C1 by placing a probe on pin-6/7.

2. Use the theory that you learnt in Part 2 to calculate the time period for the circuit when timing both soft- and hard-boiled eggs (note that resistor R3 is in series with either R1 or R2 when you calculate the total resistance through which C1 is charged).

3. How would you alter the circuit to give a four-minute egg?

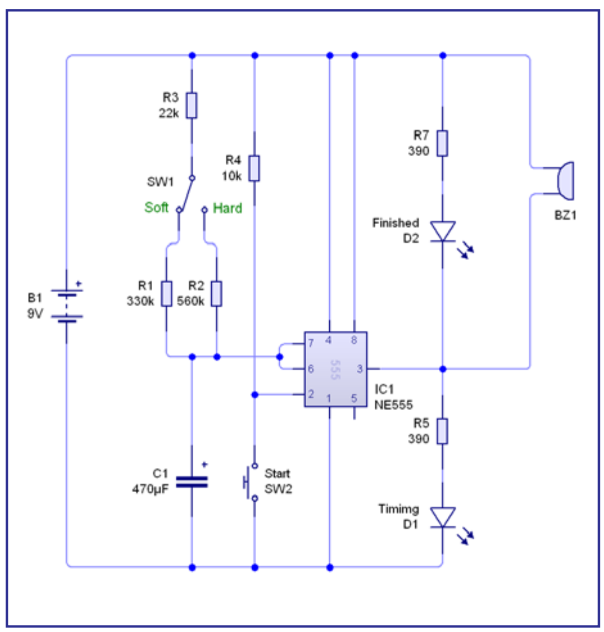


Fig.11.7. Egg timer circuit diagram

KNIGHT RIDER LIGHTS

Description

In Fig.11.8, a 4017 decade counter is used to produce a 'running lights' sequence illuminating each LED in turn. Each LED is connected to two outputs, so that as the 4017 counts up further, the LEDs are lit again in reverse order. This gives the effect of the LEDs running alternately forward/backwards.

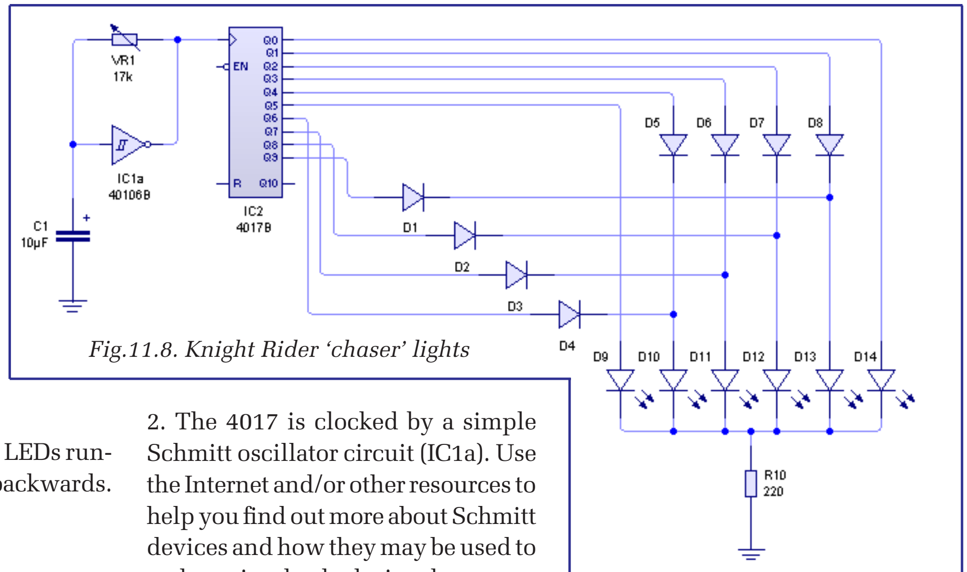


Fig.11.8. Knight Rider 'chaser' lights

Investigate:

1. The speed of the lights can be varied by 'adjusting' potentiometer VR1. Check that this works.

2. The 4017 is clocked by a simple Schmitt oscillator circuit (IC1a). Use the Internet and/or other resources to help you find out more about Schmitt devices and how they may be used to make a simple clock signal.

3. What is the purpose of diodes D1 to D8?

4. Why is only one series resistor (R10) required?

INTRUDER ALARM

Description

The circuit shown in Fig.11.9 uses a thyristor (or silicon controlled rectifier (D1)). We've not met this particular device before, but it acts as a *latch* to hold the circuit in the 'on' state once pushswitch (push-to-break) SW1 is pressed.

The alarm will remain on until the circuit is disconnected from the battery (for example with keyswitch SW2), even if SW1 is released. Switch SW1 could be replaced with a normally closed (NC) pressure pad, a trip wire or a door contact in a real circuit.

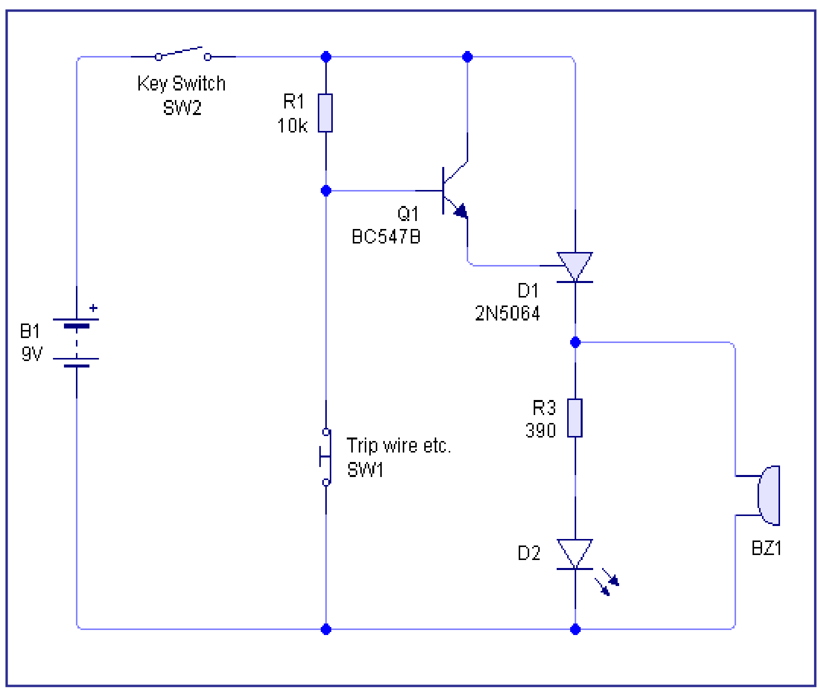


Fig.11.9. Circuit diagram for a simple intruder alarm

Investigate:

1. Extend the circuit to include more than one trigger.

2. Use the Internet and/or other resources to find out how a thyristor works.

3. What would happen if (a) resistor R1 became open-circuit or (b) if transistor Q1 became short-circuit between collector and emitter?

For more information, links and other resources please check out our Teach-In website at:
www.tooley.co.uk/teach-in

Build – The Circuit Wizard way

PUSH-ON/PUSH-OFF CONTROL SWITCH

Description

In Fig.11.10, a J-K flip-flop is clocked on/off when pushswitch (push-to-make) SW1 is pressed. The Schmitt trigger inverter (IC2a) and capacitor C1 are used to de-bounce the clock input of the flip-flop. The output triggers transistor Q1, which in turn allows current to flow though the coil of the relay (RL1), and hence completes the mains voltage circuit and powers the lamp. In this way, the same pushbutton may be used to turn the light on and off.

Investigate:

1. What is switch 'bounce' and why do we need to reduce it?
2. What would happen if SW1 was not debounced properly?
3. What is the purpose of diode D1?

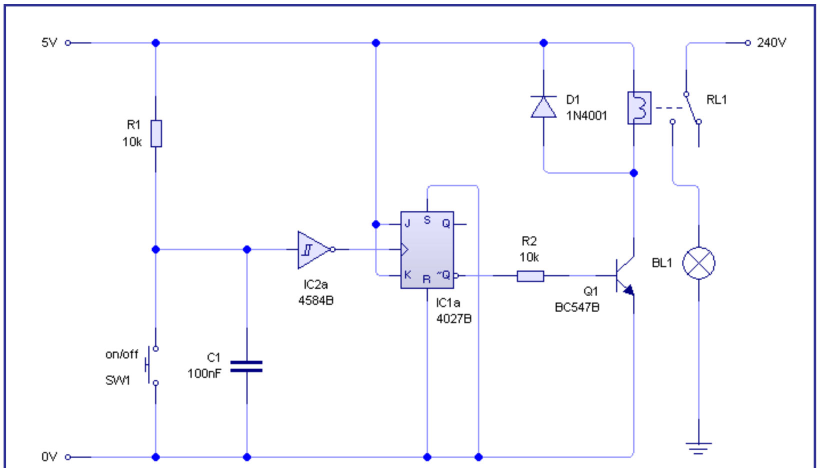


Fig.11.10. Circuit for a push-on/push-off control switch

9V BATTERY TESTER

Description

The battery tester circuit (Fig.11.11) uses three consecutively higher breakdown voltage Zener diodes to control red, amber and green LEDs to indicate the battery voltage. We have used a variable power supply to simulate the voltage of the battery on test.

Investigate:

1. Why do resistors R1 to R3 need to be different values?
2. What would the effect be of changing the breakdown voltage of the Zener diodes?
3. How would you alter this circuit to test other battery voltages – eg, 5V, 12V etc.?

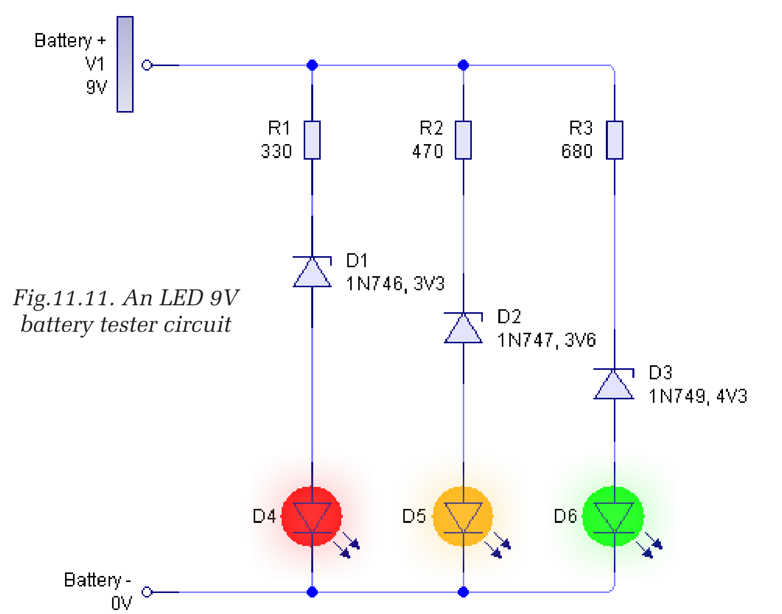


Fig.11.11. An LED 9V battery tester circuit

METRONOME

Description

A 555 timer is used in Fig.11.12 in an astable configuration. The frequency of the output is controlled by adjusting variable 'resistor' VR1, which varies the speed at which capacitor C1 is charged/discharged. As the output (pin 3) changes from 0V to 9V, LEDs D1 and D2 are lit alternately. Note that Circuit Wizard will not simulate the 'tick' that you would hear from the speaker as the output changes in the real circuit.

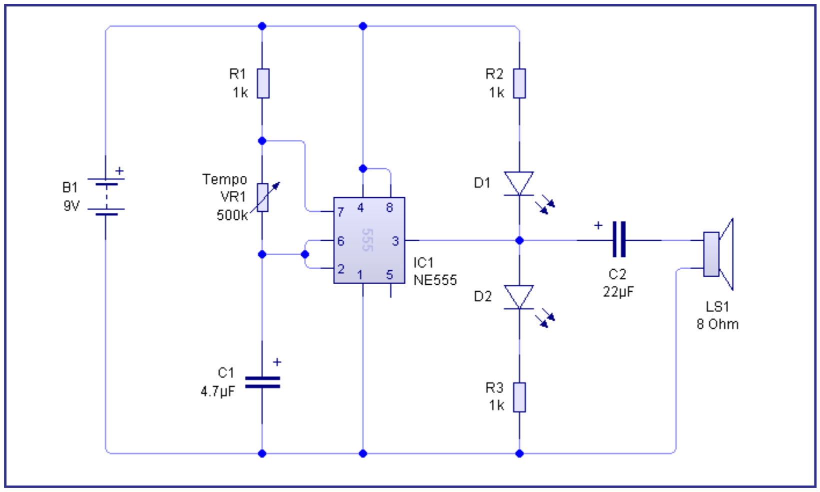


Fig.11.12. Metronome circuit using a 555 timer IC

Investigate:

1. What is the purpose of capacitor C2?

2. How could you add an additional range of tempo that would be (a) ten times slower or (b) ten times faster than the original rate? What single component would need to be changed?

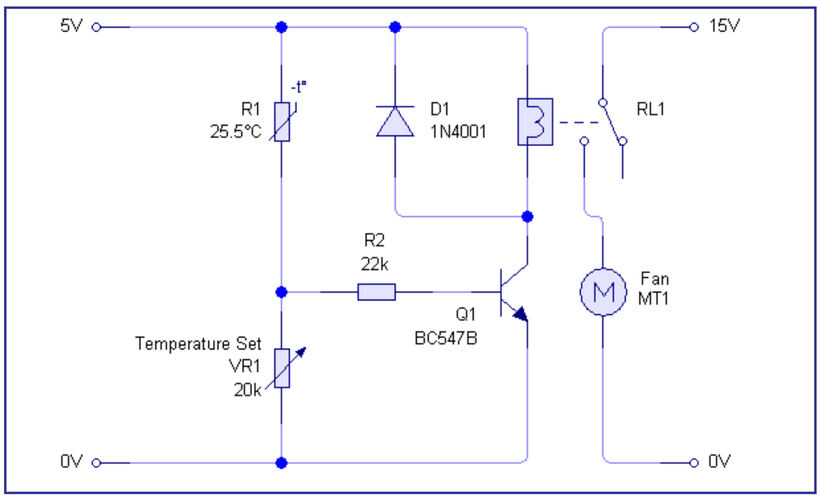


Fig.11.13 (above). Temperature-controlled fan circuit

TEMPERATURE-CONTROLLED FAN

Description

A simple potential divider-driven sensor circuit is shown in Fig.11.13. As the temperature changes, the resistance of the thermistor (R1) changes accordingly. This affects the voltage at the base of the transistor. Once this voltage is sufficient, the transistor will allow current to flow trough the coil of the relay down to ground (0V), thus completing the fan circuit. Varying VR1 will adjust the point at which the fan is activated.

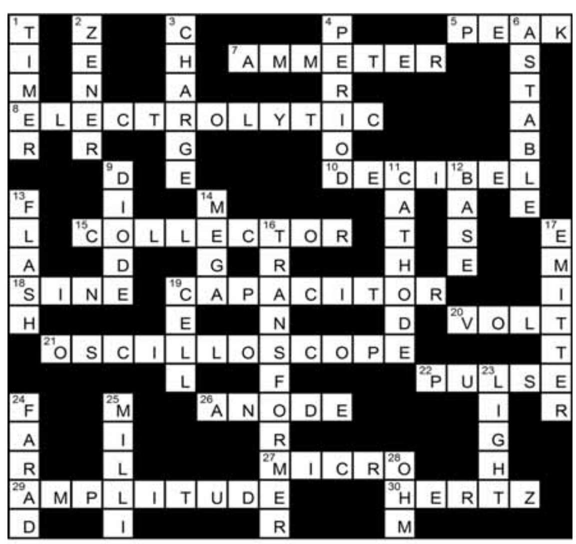
Investigate:

1. How could you improve this circuit by using an operational amplifier?

2. What would happen if the thermistor went open-circuit?

3. What does diode D1 do? Use the Internet and/or other resources to find out.

Fig.11.14 (right). Answer to Question 11.1



Answers to Check questions

11.1. See Fig.11.14

11.2. (a) switch (SPST)

(b) resistor (fixed)

(c) transformer (iron cored)

(d) light emitting diode (LED)

(e) capacitor (fixed, non-elec trolytic)

(f) variable potentiometer

(g) electrolytic capacitor

(h) AND gate

(i) operational amplifier

(j) cell (or battery)

(k) preset potentiometer

(l) variable capacitor

(m) NPN bipolar junction transistor (BJT)

(n) R-S bistable (or flip-flop)

(o) bridge rectifier

11.3. (a) sinewave

(b) 40Hz

(c) 25ms

(d) 5V.

11.4. (a) pulse (repetitive)

(b) 5ms

(c) 200Hz

(d) 20%

(e) 3.5V

11.5. V; electric current; watt; farad; Ω; hertz; bits per second

11.6. one volt; one amp; a power of one watt is equivalent to one joule of energy being used every second; one ohm; a signal has a frequency of one hertz if one complete cycle occurs every second

11.7. (a) 0.25V

(b) 150μA

(c) 68kΩ

(d) 235mW

(e) 220kΩ

(f) 0.885kHz

(g) 1.5nF

(h) 1200bps.

11.8. (a) resistors (4)

(b) preset potentiometers (2)

(c) slide switch (DPDT)

(d) light emitting diodes (2)

(e) transistors (2)

(f) electrolytic capacitors (2)

(g) printed circuit board

(h) battery (9V PP3 type)

(i) battery connector.

11.9. See Fig. 11.15

11.10. (a) electrolytic capacitor

(b) *PNP* transistor

(c) R1 and R2

(d) brown, red, yellow, gold

(e) RV1

(f) 6V

(g) 3.54V

(h) R2.

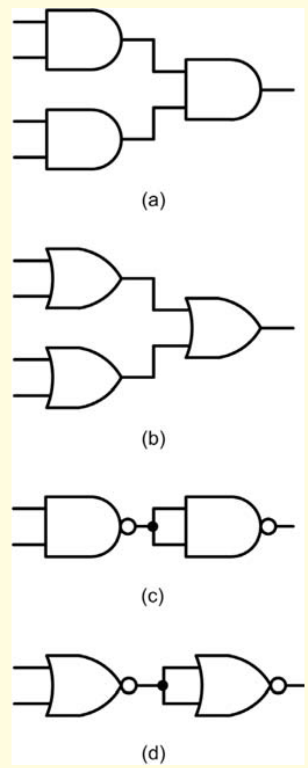


Fig.11.15. Answer to Question 11.9

Round-up

Over the last ten parts of our *Teach-In 2011* series, we've attempted to cover the core electronics syllabus taught in many schools and colleges in the UK. We've introduced each of the main topics studied at Level 2 (equivalent to GCSE) as well as a few that bridge the gap into further studies at Level 3 (equivalent to A-level).

'Build' provides you with eight additional circuits to build and investigate using the Circuit Wizard software. All of these circuits can be modified and extended and we've suggested how this can be done and things that you might want to try. As mentioned previously in our series, you can learn a great deal by experimentation.

Finally, we tried to keep the mathematics to a level that is sufficient to understand and apply the underpinning theory (for example, to calculate the values required to achieve a particular time constant in a *C-R* circuit). If you are intending to progress to higher level courses in electronics, you will require further study of mathematics at Level 3, but please don't let this put you off – the most important thing is to develop a 'feel' for how electronic circuits behave and the best way to do this is to do it the 'practical way'.

Good luck with your studies of electronics and don't forget that 'sums + circuits = understanding'!

Mike and Richard Tooley

TEACH-IN 2011 – *Topic Index*

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Attending to noise and stability

CHAT ZONE contributor ***741*** posted the following question about using op amp amplifiers with gains of less than unity (that is attenuator circuits).

Is there any reason not to use a fractional gain inverting amplifier? Here is an example [See Fig.1], *Vo= –Vin/3.?*

If you build the circuit in Fig.1 there is a reasonable chance that it will work. However, it may prove to be unstable, depending on the op amp used and the gain setting. Furthermore, there are potential issues with noise and offsets.

Although 741 is interested in an inverting circuit, it is instructive to consider both basic op amp amplifier configurations – the inverting (Fig.2) and non-inverting amplifiers (Fig.3). We will need to use the properties of both circuits to analyse the inverting amplifier, as we will see later.

The expressions for closed-loop gain (circuit gain with feedback), A_{CL}, of the two amplifier configurations, are, with reference to Fig.2 and Fig.3: *–R2/R1* for the inverting and (1+*R2/R1*) for the non-inverting. These show that only the inverting circuit could be used directly as an attenuator. The '1' in the non-inverting gain equation ensures its gain cannot be less than one, irrespective of any practicalities as to what resistors values might be usable in a real circuit.

Feedback block

When analysing circuits and systems with feedback, it is common to abstract the design to a feedback block diagram. These are shown in Fig.4 and Fig.5 for the inverting and non inverting amplifiers respectively. We looked at this topic in depth in the April and May *Circuit Surgery*

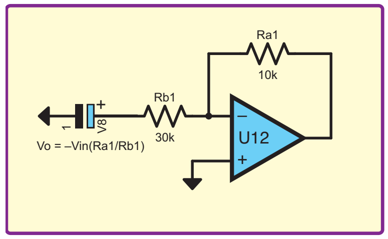


Fig.1. Copy of 741's first example circuit

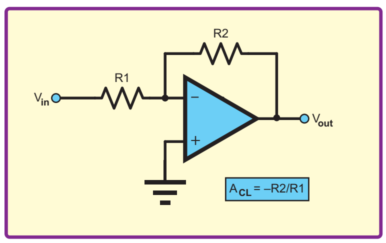


Fig.2. Op amp inverting amplifier

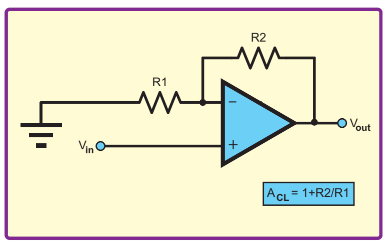


Fig.3. Op amp non-inverting amplifier

articles, so will not go into so much detail here. If you do not have the earlier issues an online search for 'negative feedback gain' should help.

In the feedback diagrams, *A* is the open-loop gain of the op amp and β is the feedback fraction – the proportion of the output which is fed back. α in the inverting circuit structure is also a scaling factor. In the May issue, we showed that α = 1–β. Analysis of the feedback structures provides us with generalised expressions for closed-loop gain (gain of the whole circuit) in terms of A, β and α.

$$\text{Inverting} \qquad A_{CL} = \frac{\alpha A}{(1+\beta A)}$$

$$\text{Non-inverting} \quad A_{CL} = \frac{A}{(1+\beta A)}$$

We showed how to obtain these equations in detail in the April and May articles.

Of particular importance when considering these two equations is that *A* is typically very large (typically hundreds of thousands or millions for op amps) and β is typically a moderate fraction (say in the range hundredths to unity). Thus βA is typically much larger than 1 so (1+ βA) is more or less the same values as βA. If we remove the 1 from the equations we can simplify them by cancelling out the *A*, leaving:

$$\text{Inverting} \qquad A_{CL} = \alpha \frac{1}{\beta}$$

$$\text{Non-inverting} \quad A_{CL} = \frac{1}{\beta}$$

Inspection of the circuits in Fig.2 and Fig.3 reveals that the feedback is provided by the potential divider formed by the two resistors. Using the formula for a potential divider, we find that for both circuits:

$$\beta = \frac{R1}{(R1+R2)}$$

From this, and given that α = 1–β, we can easily derive the closed loop gain equations in terms of the resistor values. The fact that the β is the same for both configurations, but the closed-loop gains are different is of importance.

Noise gain

The value 1/β is called the **noise gain** of the circuit and is relevant to the amount of noise and offset we see at the

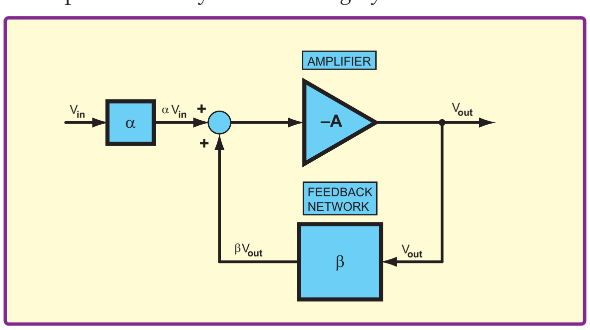


Fig.4. Feedback structure for the inverting amplifier (Fig.2)

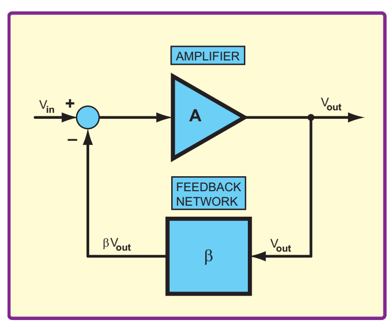


Fig.5. Feedback structure for the non-inverting amplifier (Fig.3)

output of both op amp amplifier configurations. We discussed noise in detail in last month's *Circuit Surgery,* so will not go into a lot of detail about how to perform noise analysis here. The noise voltage produced by an op amp, as stated on the datasheet, is input-referred to the non-inverting input. The noise voltage, v_N, stated (typically in nV/√Hz) can be viewed as a voltage source connected to a noiseless op amp, as shown in Fig.6.

To perform a noise analysis of the two op amp amplifiers in Fig.2 and Fig.3, we replace the op amps with the noise model shown in Fig.6. We also ground the input signal, as this is not included in the analysis (we assume it is noise free and so equal to 0V). This is shown in Fig.7 and Fig.8

It should be obvious that the two noise analysis circuits are identical, despite the fact that the original circuits were different. In both cases, as far as the noise voltage source is concerned, the circuit acts as a non-inverting amplifier with a gain of $1/\beta$, or 1+ R2/R1 in terms of the component values.

The previous discussion leads us to the, perhaps surprising, conclusion that the gain by which noise is amplified is not necessarily the same as the closed-loop signal gain of the circuit. In both cases, the noise gain is $1/\beta$, which is why this term is referred to as noise gain.

For the inverting amplifier, the open-loop gain is –R2/R1 and the noise gain is 1+R2/R1. For large gains, this will not make much difference, for example if the inverting circuit gain is 200 the noise gain will be very similar at 201.

For small gains, however, the difference is more significant. If R2/R1 = 0.3, as in 741's fractional gain example, the circuit gain is –0.33 and the noise gain is four times larger at 1.33.

Current input noise

So far, we have only considered the op amp's voltage noise; there is also current input noise (which is generally less significant) and noise from the resistors to consider. If the non-inverting input noise current flows through any impedances (it does not in our circuits) then the resulting voltage would be amplified by the noise gain. Noise in R1 is amplified by the circuit voltage gain, not the noise gain.

Offset voltages are treated in a similar way to noise. The op amp's input offset voltage (another datasheet parameter) is represented like Fig.6, but with the input offset voltage instead of v_N and an offset-free amplifier. It follows that input voltage offsets are amplified by the noise gain and that, like noise, this may be significant in inverting amplifiers with low closed-loop gains.

Application of feedback to an amplifier may result in instability. This unwanted oscillation is very undesirable, so we need an understanding of how this might occur in order to design to prevent it. As we have seen, both standard basic op amp amplifier circuits use negative feedback and so may suffer from stability problems in certain circumstances.

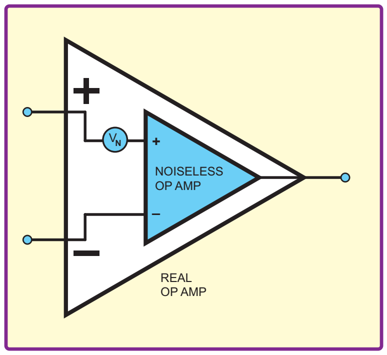


Fig.6. Representing the noise produced by an op amp

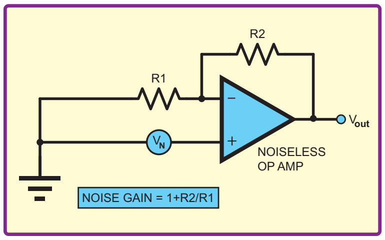


Fig.7. Op amp noise analysis for an inverting amplifier based on Fig.2. and Fig.6. Note this is the same as Fig.8.

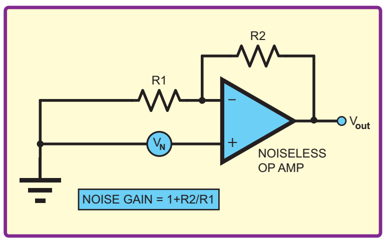


Fig.8. Op amp noise analysis for a non-inverting amplifier based on Fig.3. and Fig.6. Note this is the same as Fig.7.

Instability

Consider the closed-loop gain equation for the non-inverting configuration stated earlier:

$$A_{CL} \;=\; A\,/\,(1+\beta A).$$

If the value of $(1 + \beta A)$ approaches zero, then closed-loop gain will approach infinity. This results in instability; specifically the circuit oscillates. The condition for which $(1 + \beta A) = 0$ is $\beta A = -1$. Since A and β have magnitude and phase shift it is often more useful to express the condition for instability as: $|\beta A| = 1$ and the phase shift due to βA is ±180°. The vertical lines around $|\beta A|$ mean 'absolute value of' – that is the value of βA without regard to the sign.

Looking at the closed-loop equation for the inverting amplifier we see that the equation 'blows up' when $(1 + \beta A) = 0$ in exactly the same way as the non-inverting case. For a given op amp (and hence value of A) it is β that will determine the stability of the circuit. Thus, we can conclude that it is noise gain $(1/\beta)$, rather than closed-loop circuit gain, which fundamentally influences the stability of both types of op amp amplifier.

Phase shift

It is the phase shift in the amplifier circuit which is responsible for instability, so it worth looking at this in more detail. The output of an amplifier does not respond infinitely quickly to changes at its input, so any signal fed back from the output to the input will be offset in time with respect to the original input.

Consider a simple case in which there is a fixed delay from input to output of a circuit whatever the input signal does (things are usually more complicated than this). Say, for example, this delay was 0.1µs. If the input frequency was 100Hz this time would be 0.001% of the signal's cycle time and could probably be considered insignificant.

However, at 2.5MHz the 0.1µs delay is a quarter of the signal's cycle time of 0.4µs. This would usually be expressed by saying that the circuit had a phase shift of 90° at 2.5MHz (one complete cycle of the waveform is 360°). At 5MHz 0.1µs is half the cycle time of the signal. This is a significant point because a phase shift of 180° is equivalent to multiplying the signal by –1.

Consider the total phase shift through the amplifier and feedback network as we increase the input signal frequency. Once this reaches 180° we have effectively inverted our feedback signal – what was negative feedback has become positive feedback. Positive feedback is what you need to make an oscillator, so our amplifier may become unstable.

The reason that all amplifiers do not become oscillators is because as frequency and hence phase shift increase the gain decreases. By the time the phase shift has reached 180° the gain has hopefully decreased below the point at which oscillation can be sustained (it is less than unity).

Phase and gain margins

If we are building an amplifier we must avoid oscillation and it is useful to know how far away our circuit is from potential instability. This can be measured in a couple of related ways – phase margin and gain margin.

As $|\beta A|$ approaches 1, the phase shift is less than 180°. The difference between the phase at this point and 180° is the *phase margin*

As the phase shift of βA approaches ±180° $|\beta A|$ may be less than 1. This difference can be expressed as the *gain margin* (usually in dB).

Gain margin and phase margin are illustrated in Fig.9, which shows the variation of $|\beta A|$ and phase shift of βA with signal frequency. Note that a gain of 1 is 0dB and that the phase shift is negative because the output lags behind the input signal in time.

The larger the feedback fraction β the more 'difficult' it is to fulfil the gain and phase margin stability criteria because the feedback signal is stronger and less likely to get down to unity by the time the phase shift gets to 180°. Thus a circuit configuration could, for example, be stable with β=0.5, but not with β=1.0. It is not just the designed components which affect

stability – things like circuit load and stray capacitance can have a significant impact on the variation of $|\beta A|$ and the phase shift of βA with signal frequency.

The decrease in gain with frequency for an op amp it not arbitrary, it is part of the design of the op amp. Introducing circuitry to modify how gain and phase shift change with frequency in such a way as to ensure stability is known as **compensation**. Most op amp ICs are compensated to guarantee stability down to unity gain, but not all are. If an op amp is only guaranteed stable down to, say, a gain of 5 then it will not be stable in the circuit in Fig.1.

The fact that noise gain and circuit gain are different gives us some potential to trade off noise/offset and stability. We can make the noise gain higher for stability, while keeping the low circuit gain (attenuation). An example is shown in Fig.10. The gain for the signal is $-R2/R1$ as before because as far as the inverting circuit is concerned $R3$ is like an input to a summing amplifier with zero signal applied. When we analyse the circuit in Fig.10 as a non-inverting amplifier working on the noise we use the parallel combination of $R1$ and $R3$ rather than

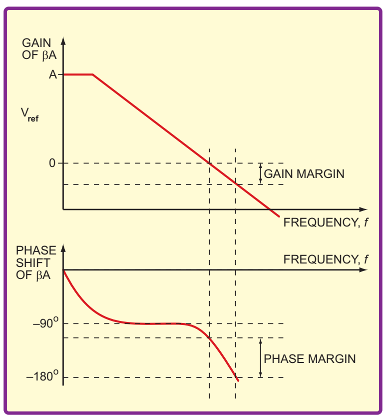


Fig.9. Variation of a $|\beta A|$ and phase shift of βA with signal frequency illustrating gain margin and phase margin

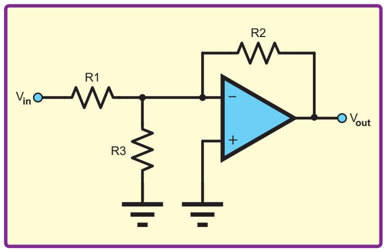


Fig.10. Adding a resistor to adjust the noise gain for stability

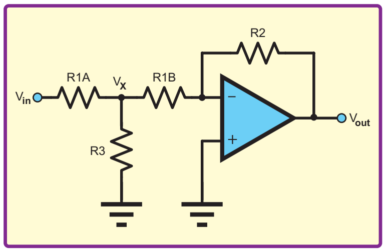


Fig.11. Stable inverting attenuator

just $R1$ in the gain calculation (call this R_p) so the noise gain is $1+R2/R_p$.

Using the same values as Fig.1 and adding R3=5kΩ would give a noise gain of 3.3, which may be more stable than 1.3. The circuit gain is still 0.33.

Fig.11 shows another op amp attenuator, this is like Fig.10, but with $R3$ connected in the middle of a split $R1$. Calculation of resistor values for this circuit is more complex, but is simplified if we use normalised values and then scale up to the required resistance values later. For this reason we set $R1A = R1B = 1$ and $R2 = 2$.

We can think of the circuit in Fig.11 as an inverting amplifier amplifying the voltage, V_X, at the $R1/R3$ junction. The gain of this amplifier is 2 by virtue of the normalised values we have already set. The voltage V_X is given the action of the potential divider formed by $R1$ and $R3$ on the input voltage. More specifically, this potential divider is formed by $R1A$ and the parallel combination of $R1B$ and $R3$ (call this parallel value R_p). The total gain of the circuit, G, is therefore the inverting amplifier gain (2) times the potential divider factor, so we have:

$$G = \frac{2R_P}{(R3 + R_P)}$$

The value of R_p is as follows (noting that $R1B = 1$):

$$R_P = \frac{R3}{(R3+1)}$$

We substitute this value of R_P into the equation for G and obtain an expression which just contains G and $R3$. After a bit of algebraic manipulation to rearrange and simplify things, we can get a formula to set $R3$ based on the gain we want.

$$R3 = \frac{G}{(2-2G)}$$

For example, for a gain of one third (as in Fig.1) we get $R3 = 0.25$. If we choose $R1A = R1B = 10\text{k}\Omega$, the other values scale proportionally, so R2 = 20kΩ and $R3 = 2.5\text{k}\Omega$. If the source driving V_{in} has significant output impedance this should be taken into account when selecting resistor values (eg, by reducing $R1A$ accordingly).

There is a useful article from Bruce Carter of Texas Instruments which discusses the attenuator circuit in Fig.11 in more depth, and also looks at a fully differential version. According to the article, there is an online utility (called RESISTOR-CALC) on TI's website which will calculate resistor values for this circuit, but at the time of writing it did not seem to be functioning.

Reference

Bruce Carter, 'Op amp attenuators', *Texas Instruments Analogue Applications Journal*, Fourth Quarter, 2003, pages 28 to 30. **http://focus.ti.com/lit/an/slyt051/slyt051.p**

Max's Cool Beans

By Max The Magnificent

Acting mentor

Recently, I've been hearing from young engineers who have started their first jobs, but are finding themselves out of their depth with nowhere to turn. The way things used to work when I began my career was that each newcomer was assigned to an older, more experienced engineer who acted as a mentor. If you were lucky – and I was – you got someone who delighted in teaching you the tricks of the trade.

After graduating with a BSc in control engineering in the summer of 1980, my first position ('Look mum, a real job!') was with International Computers Limited (ICL) in Manchester, England. At that time, ICL made honking big mainframe computers, and I was hired as a member of one of their central processing unit (CPU) design teams.

It didn't take me long to discover that little of what I'd studied at college had much bearing on my new job. I also quickly realised that tasks that had appeared easy in the classroom were somewhat trickier when you had to do them in earnest. Fortunately, ICL had a really good policy whereby junior engineers like me were partnered with more experienced team leaders. I was lucky in this regard to be assigned a mentor called Dave Potts, who taught me far more than I'm sure he ever realised.

As one example, my first task at ICL was to design a 128-bit barrel shifter/rotator; that is, a unit that could shift or rotate the contents of the 128-bit data bus by any amount from 1 to 128 bits in a single clock cycle. The idea was to design a special silicon chip and to then use eight of these chips to implement the shifter/rotator, where each chip would handle a 16-bit chunk of the data bus. All of the chips were to be functionally identical in order to keep the project within budget.

As an aside, I should point out that we were designing gate-level schematics using pencil and paper; also, the chips in question each contained only around 2,000 equivalent logic gates (these devices were considered to be pretty much state-of-the-art at the time).

Initially, my task didn't appear to be particularly arduous. The only tricky details involved working out what data I needed to 'stuff' into the 'ends' of the shifter/rotator. In the case of a logical shift right, for example, you shift the appropriate number of logic 0 values into the left-hand side of the shifter. By comparison, in the case of an arithmetic shift right, you shift in copies of the original sign bit. As I recall, part of my solution was to employ a couple of the pins on each of the chips to act as a device ID. These pins could be hardwired to logic 0 and 1 values on the circuit board, thereby informing each chip as to its position in the chain.

When I'd completed the first part of the exercise, Dave deigned to inform me that he'd neglected one slight detail, which was that – in addition to being able to process all 128 bits from the data bus – the shifter/rotator also had to be capable of working with only the least-significant 64 bits or the least-significant 32 bits. So my task had just become a little trickier, but it still wasn't all that bad and a few days later I returned with my latest offering. 'Ah, Ha!' said Dave, 'Now we're getting there, but in addition to working with binary values, this device also has to be able to handle 128, 64, or 32-bit binary-coded decimal (BCD) data.'

Dave then proceeded to explain the concepts behind BCD in general, along with what shifting/rotating this form of data entailed. For example, since each BCD digit occupies four bits, it was only possible to perform shifts in four-bit (one nibble) increments. Also, when performing an arithmetic shift right, I had to shift an appropriate number of copies of the sign nibble into the left-hand side of the shifter.

And so it went. Every time I finished working on a problem, another feature would be added to my portion of the project. In reality, of course, the main specification already contained all of these details, but if I'd been presented with the full requirements on my first day, my brains would have leaked out of my ears and I would have been reduced to a gibbering wreck.

Endless patience

The great thing was that Dave was endlessly patient and he was always available to answer questions and to offer suggestions as to different ways to do things and cunning logic tricks one might employ. Looking back with hindsight (the one exact science) I realise just how lucky I was. If I had simply been presented with the full-up specification for the shifter/rotator on the first day, I wouldn't have known where to start. The result could well have been to ruin my self-confidence and to leave me feeling like a failure, which would almost certainly have negatively affected the rest of my career. By comparison, the way Dave broke things down into sub-projects, only ever giving me tasks I could handle (even if I had to think about them for a while) really built up both my knowledge and my confidence.

Any ideas?

The problem is that very few companies seem to use any form of mentoring these days. Instead, they take the attitude that when a student leaves college he or she should be ready to hit the ground running. In my experience, this is rarely the case. Of course, there are various online training resources available for continuing education, but there's nothing as good as having access to someone more experienced with whom you can ask questions and bounce ideas around.

How about you? Have you had experiences of this sort of thing – either as a mentor or as a new engineer who had (or did not have) a mentor? And what would you suggest that newcomers to the industry do in the absence of a mentoring program? Please write in to the *EPE* letters page and share your insights with the rest of us.

Until next time, have a good one!

Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

IF YOU are not careful, locating and buying all the components for a project can be a very time consuming business. Going about things in a totally disorganised fashion could result in more time being spent obtaining the components than actually assembling them! It is probably fair to say that the size and complexity of electronic projects has reduced somewhat over the years, and the days when a 'mega' project had to be carefully assembled over a period of weeks or even months are probably behind us.

Even so, many projects require a fair number of components, and obtaining a full set of them is potentially a time-consuming business. It is worth putting in some time and effort into getting to know the strengths and weaknesses of the various component suppliers. Where there are printed catalogues available it is a good idea to obtain them and to spend some time studying their contents.

Information superhighway

As with much else in the retail world, the sale of electronic components is now largely via online ordering rather than over-the-counter or using traditional mail or telephone ordering. While it is not essential to have an Internet connection in order to pursue the hobby of electronic project construction, being without one is likely to be a significant hindrance.

In addition to providing access to online electronic component catalogues, the Internet makes available a huge amount of data and other information from the websites of the semiconductor manufacturers. In fact, there is a massive amount of information available on a wide range of components, from simple passive types such as resistors and capacitors to the highly specialised devices such as gas sensors. Last, and certainly not least, there is the *EPE* website and Alan Winstanley's highly regarded guide to soldering (**www.epemag.wimborne.co.uk/solderfaq.htm**).

Whether you rely on a conventional catalogue, the online variety, or a mixture of the two, it is a good idea to study them carefully. Apart from learning the types of component available from each source, component catalogues often have a great deal of information that is helpful to beginners.

There will often be some connection data for semiconductors, physical dimensions and mounting details for switches, relays, and so on. In the case of online catalogues, there will be links to the manufacturers' data sheet for many of the components, and for practically all of the semiconductors.

Mail order

Postage and packing charges can add significantly to the cost of building a project, but this just has to be accepted as a fact of project building life. In order to minimise this additional cost it obviously makes sense to obtain all the components from a single source, but in many cases it is likely that there will be no single supplier that has everything required.

Many projects have one or two highly specialised components such as sensors and complex integrated circuits, and these might have to be obtained from a different source to the other parts. If the project is based on a custom printed circuit board (PCB) it will have to be obtained separately, unless you make your own. Initially, it is advisable to use ready-made boards.

It helps if you plan ahead by purchasing the components for two or three projects at a time so that the number of orders is minimised. The suppliers that deal mainly with hobbyists either have no minimum order value, or if there is one it will be set at a relatively low level. The large professional suppliers of electronic components have an amazing range on offer, and will accept orders from non-professional customers. These days they are very important sources of supply, but there will typically be a minimum order value of about £20 for non-account customers.

Again, planning ahead can be useful here, and can help to bring an otherwise inadequate order value above the minimum order threshold, in addition to keeping down postage costs. It also helps to bear in mind that these large professional suppliers offer more than just electronic components. If you need some hacksaw blades, or a new hacksaw for that matter, there will probably be several to choose from.

Stock market

There is a risk of delays occurring when you finally start construction and discover that a commonplace but crucial component has been overlooked or is broken. Delays can also occur if one or more of the parts are out of stock at the retailer. Improvements in logistics mean that delays of this type tend to be relatively rare and short these days, but they can still be very frustrating.

I would guess that every electronic project builder decides sooner or later that it is worth having a stock of the more everyday components. This removes the need to buy every single component for a project, right down to the last nut and bolt. The expensive and more specialist items still have to be purchased in the normal way, but all or most of the more mundane components are taken from a stock of such items. This makes ordering the components much quicker and can help to avoid frustrating 'out of stock' delays.

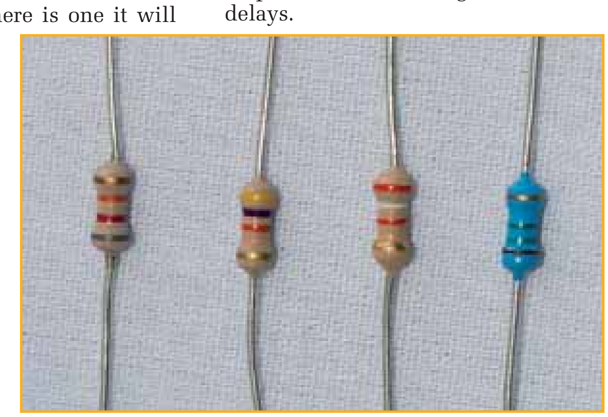


Fig.1. Although small resistors such as these are available in a large range of values, producing a large stock of them does not have to cost very much

The obvious problem when building up a stock of components is to decide which ones to buy. There is no point in buying components that will not be used for many years, or never at all. It is probably best not to stock any expensive components at all. Doing so would greatly increase the cost of the stock, and there would be no guarantee that any of the highly priced components would ever be used. Even a few remaining unused would represent a substantial waste of money.

Building up a stock of inexpensive components is a different matter. However, even with these it makes sense to concentrate on components that are used very frequently. Resistors are the obvious starting point, as they are the cheapest electronic components and are probably used in larger numbers than any other type of electronic part.

Even with resistors you have to take a down-to-earth approach since there is no point in building up a stock of the more expensive and rarely used types. This mainly means close tolerance (1%) or high wattage types.

Most projects use carbon film resistors having a power rating of about 0.25 to 0.5 watts and a 5% tolerance rating (Fig.1). These are very cheap, require little storage space, and it does not cost a fortune to buy several hundred of them.

This is just as well, since resistors come in a very wide range of values, many of which are used a great deal. Obtaining several of each value therefore means buying at least a few hundred resistors. Some resistor values crop up much more often than others, so it is advisable to buy more of the popular values and less of the ones that are used infrequently.

It tends to be the middle values from about 1kΩ to 100kΩ that are used the most. Values above 1MΩ and below 100Ω are used very infrequently. Probably the most popular values of all are 1kΩ, 4k7, 10kΩ, 47kΩ, and 100kΩ, with the closest values to these (820Ω, 1k2, 3k9, etc.) being used very much less. The extra values in the E24 series (1.1, 1.3, 1.6, etc.) are not used a great deal in projects, and it is not worth stocking them.

Fig.2. In order to be really useful a stock of components must be well organised so that the required parts can be located quickly. Inexpensive miniature chests of drawers are idea for storing components in an organised fashion

Under development

The resistor development packs offered by some suppliers represent the easiest way of obtaining a large stock of resistors. Few offer a full range of values, and they typically cover all the normal E12 range of values from 10Ω to 1MΩ. Presumably, because the very high and low values are little used in modern circuits they are not usually included, but it is helpful if a few of these are obtained separately. The resistor kits currently on offer do not seem to vary the quantities to suit the typical usage of each one, so it can be useful to buy extra supplies of the most popular values. An advantage of buying a large resistor pack is that the price per resistor can be relatively low, and in some cases is well under one pence per resistor.

The advice often given by magazines in the past, was to build up a stock of resistors by obtaining two or three times as many as you actually needed. For example, if a project needed three 10kΩ resistors you would actually order six or nine of them. The big advantage of this method is that there is no ‘up front’ cost, and you should barely notice the increase in the cost of each components order. The drawback is that it can take quite a while to build up a really useful stock of resistors.

There is another advantage to this method, which is its built-in weighting. Without having to put any thought or effort into it, you will buy larger quantities of the popular values, and fewer of those that are little-used. The quantities needed in the past will not necessarily reflect your future needs with a high degree of accuracy, but in practice, it likely to be more accurate than any other method.

Of course, the same method can be applied to other components, but it should only be applied to the cheaper and more frequently used components. It cannot usefully be applied to any components that cost more than ‘peanuts’ or are in any way out of the ordinary.

High capacity

Building up a useful stock of capacitors is likely to be more difficult than producing a stockpile of resistors. As with resistors, a huge range of values is involved, but with capacitors there is also a variety of different types in common use. With mid-range values of around 10nF there could well be ten or twenty different types to choose from. I suppose this is simply a reflection of the fact that nothing approaching the perfect capacitor has yet been developed.

Circuit designers, therefore, have to select a type of capacitor that has suitable characteristics for each application. One application might require capacitors that are designed to work efficiently at high frequencies, while in another circuit it may be high stability and accuracy that is required. Some applications are undemanding and will work well enough with any capacitor of the correct value, but substituting a capacitor from stock where one of a different type is called for will not necessarily have the desired result.

These days, most capacitors are of the printed circuit mounting (PCM) variety, and have pins rather than long leadout wires. A capacitor of a given type can be available with two or more pin separations. While it is not impossible to use a component having the wrong pin spacing, it does not always work well and is best avoided. A further complication is that some capacitors are still available in axial versions. This is the type that has a leadout wire at each end of a tubular body, like normal resistors.

Producing a comprehensive stock of capacitors is not really a worthwhile proposition, it would require a huge number of relatively expensive components. The over-buying method can be used with capacitors, but it should be restricted to the cheapest

Fig.3. Most storage drawers have provision for adding labels that make it easier to find the required components

types. Over-buying with something like a very high value component or a precision type would probably be a waste of money. However, it can be worthwhile producing a stock of the more common capacitors, but it is necessary to buy them very selectively.

Probably due to their very wide tolerances, electrolytic capacitors are only generally available in the E6 range of values. They are only used to a great extent in what could be termed the E3 range (1, 2.2, 4.7, and their decades), so it is probably best to only bother with these values. The axial types seem to be used very little these days, so it is probably best to concentrate on the printed circuit mounting type. Values from 1μF to about 100μF are used a great deal, so a few of each value from this range should prove useful.

Components having a maximum working voltage of about 50V to 100V should be chosen for values up to 10μF, but a lower voltage rating of about 16V to 25V will suffice for the higher values.

In modern electronics there seems to be relatively little need for high quality capacitors having low values, and very low values are not used much at all. It is still worthwhile having some inexpensive ceramic or ceramic plate capacitors in the E6 range from about 10pF to 1nF. Capacitors from 1nF to about 470nF are mostly of the plastic foil variety (polyester, Mylar, polycarbonate, etc.), and in general it does not matter which type is used. As explained previously, the main problem is the physical differences. Having a few of each value in the E12 range with several different lead pitches would be very useful, but could be expensive.

As with resistors, it is possible to obtain development packs, but these usually have a selection of one type of capacitor rather than a broad range of values and types. In order to produce a good stock of capacitors it is necessary to have at least three or four different types. On the plus side, development packs usually represent a very cheap way of buying capacitors.

There are a few other components that it is worth buying for stock. Some general purpose silicon diodes such as the 1N4148 or 1N914 are well worth having, as are some small rectifier diodes, such as the 1N4007. Some of the more simple switches, such as the miniature toggle types are likely to be useful, as are PP3 battery clips and a large reel of solder.

It is certainly a good idea to have the popular items of hardware in stock, such as nuts, bolts, spacers, and stand-offs. Some of these are only available in largish quantities, so you will probably end up with a stock of them as a natural part of the buying process.

Storage

Having obtained a large stock of components it is essential to store them sensibly. Simply placing everything into one or two large boxes will make it difficult to find any given component. The more things are compartmentalised, the quicker and easier it will be to find the component you require. It is not difficult to make or improvise your own storage system using biscuit tins and the like. Alternatively, miniature chests of plastic or plastic and metal storage drawers (Fig.2) can be obtained from DIY superstores and elsewhere at quite low prices.

The least expensive types are adequate for an application such as this, where mainly very light bits and pieces will be stored. Organise things sensibly with (say) all the resistors from 10Ω to 82Ω in one drawer, those from 100Ω to 820Ω in another, and so on. Label each drawer so that you can quickly locate the one that contains the part you are looking for (Fig.3).

Ingenuity Unlimited

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The circuits shown have NOT been proven by us. **Ingenuity Unlimited** is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and include a full circuit diagram showing all component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: Ingenuity Unlimited, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Email: editorial@epemag.wimborne.co.uk.

Your ideas could earn you some cash and a prize!

Low-Battery Indicator – *Go/No-go*

I HAVE encountered many low-battery indicators which flicker under transient conditions, as though they are unable to 'decide' if the battery is flat or not.

The circuit diagram for a relatively simple low-battery indicator is shown in Fig.1. The voltage of the battery, reduced to a suitable level by a resistor network, is compared with a reference voltage derived from the regulated output, such that the output of the first comparator goes low when the battery voltage is less than 7.25V. (Hence the circuit in its present form is unsuitable for use with NiCad or NiMH batteries, which don't offer a high enough voltage, even when fully charged).

This output triggers a second comparator, which has so much feedback applied (between pins 5 and 7) that it effectively becomes a latching device, similar to an unusually sensitive thyristor. Correct operation may be verified by momentarily grounding the test point (TP1) at pin 5 of IC1b. The feedback resistance may be decreased in the unlikely case that good performance is not acheived using the components shown.

A low output lights the 'Low Bat' LED, and simultaneously diverts current away from the 'Power' LED, which is thus extinguished. If a more traditional red-green combination is preferred, a 1N4148 diode needs to be put in series with the green LED. The idea being to create as big a difference in forward voltage between the two LEDs as practicable. It is perhaps unfortunate that 'tri-colour' LEDs don't seem to be widely available in a common-anode configuration.

A fairly large capacitor at pin 6 of IC1b prevents false triggering when power is intially applied; the capacitance may be increased if required. Total current consumption is about 20mA. High load currents may require a heatsink for the 7805.

S G Mitchell,
Lurgan, Co. Armagh

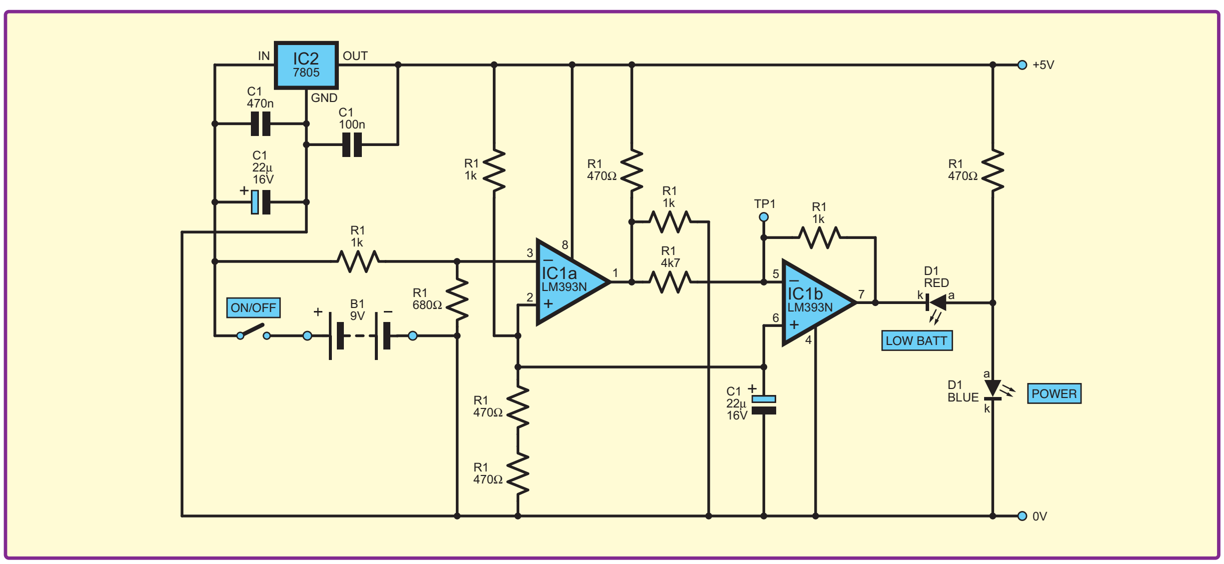

Fig.1. Circuit diagram for a low-battery indicator

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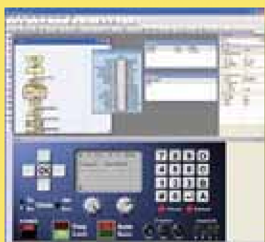
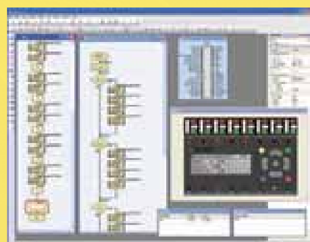


Design

Flowcode contains standard flow chart icons and electronic components that allow to you to create a virtual electronic system on screen. Drag icons and components onto the screen to create a program, then click on them to set properties and actions.

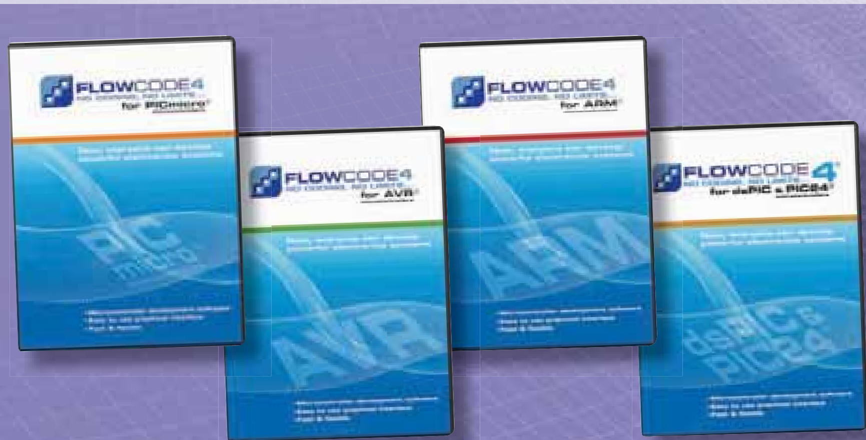


Simulate

Once your system is designed you can use Flowcode to simulate it in action. Design your system on screen, test the system's functionality by clicking on switches or altering sensor or input values, and see how your program reacts to the changes in the electronic system.

Download

When you are happy with your design click one button to send the program directly to your microcontroller based target. Targets include a wide range of microcontroller programmers, upstream E-blocks boards, the Formula Flowcode robot, the MIAC industrial controller, or your own system based on ECIO technology.



FlowKit

The FlowKit can be connected to hardware systems to provide a real time debug facility where it is possible to step through the Flowcode program on the PC and step through the program in the hardware at the same time. The FlowKit can be connected to your own hardware to provide In-Circuit Debug to your finished designs.

PRICES

Prices for each of the CD-ROMs above are: ***(Order form on third page)***

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Professional (Schools/HE/FE/Industry)	**£149**	**plus VAT**
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PICmicro TUTORIALS AND PROGRAMMING

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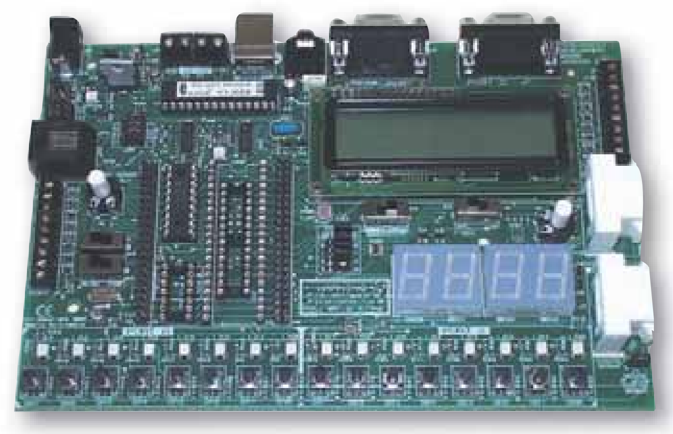


£161 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

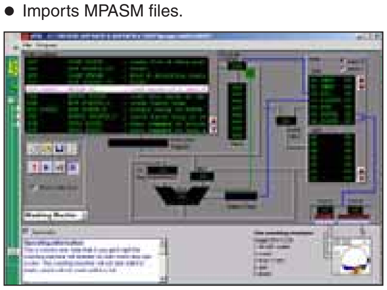
ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.

Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
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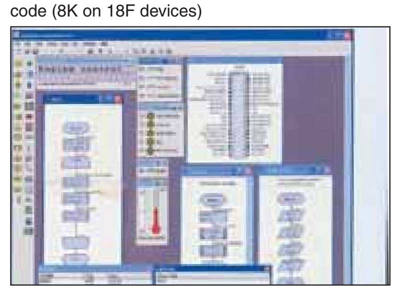
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

New features of Version 4 include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



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Professional (Schools/HE/FE/Industry)	**£99**	**plus VAT**
Professional 10 user (Network Licence)	**£350**	**plus VAT**
Site Licence	**£699**	**plus VAT**
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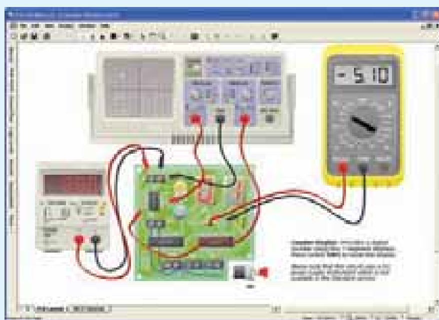

This is the software used in our *Teach-In 2011* series.
Standard **£61.25** inc. VAT
Professional **£91.90** inc. VAT

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

EPE PIC RESOURCES V2

Version 2 includes the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)

The CD-ROM contains the following Tutorial-related software and texts:

- EPE PIC Tutorial V2 complete series of articles plus demonstration software, John Becker, April, May, June '03
- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
- PIC Toolkit TK3 for Windows (software details), John Becker, Nov '01

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Note: The software on each version is the same, only the licence for use varies.

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Net Work

Alan Winstanley

Quick off the mark

FOR centuries, human beings have sought easier ways of exchanging information with their fellow mortals. Fortunately, we have come a long way since we hid paper strips inside Chinese fortune cookies, which is why in the late 1990s one of the early PDAs – the delectable Handspring Visor Deluxe – included an infra-red port enabling owners to 'beam' their business cards wirelessly to other users. I'm not sure that the idea caught on, but in an era when mobile phones were still quite primitive (they too had IR ports), beaming a contact address from one PDA to another was a neat thing to do. Handspring's Palm Graffiti handwriting recognition was well ahead of the game too.

My column last month covered QR (Quick Response) 2D barcodes, which are a small grid of pixels containing information such as a piece of text, an email address, a discount voucher code or a website URL. They can be scanned by a suitably–equipped mobile phone, webcam or 2D software and they are a slick way of 'beaming' snippets of data. More technical details can be found at the inventor's website, **www.denso-wave.com/qrcode/index-e.html**.

As well as appearing in magazine advertisements, QR codes will increasingly be seen on billboards, posters, T-shirts and wristbands, and mobile phone users will be seen taking snapshots of QR codes and stopping in the street to goggle at the results. At least one *EPE* advertiser is already using them in their artwork – simply snap the barcode with a QR-capable mobile phone, and the phone's web browser opens at the advertiser's home page.

Windows PC users can have fun with QR codes by using the Quickmark software I highlighted last month (**www.quickmark.com.tw** – free for personal use, registration required). Quickmark can use your webcam to scan larger-sized printed codes, and to test it I used the *EPE* advertisement for PoScope, which includes a small QR code (P.17, July 2011 *EPE*). My webcam could not focus or resolve sufficiently to scan the tiny code, but I did print it onto a larger sheet and Quickmark responded impressively well to a fuzzy facsimile, opening my browser at the PoScope website instantly.

The software can also be dragged across your desktop like a 'loupe' to decode any QR codes that you see on-screen. You can try it for yourself by viewing the *EPE Chat Zone* forum where I ran a thread composed entirely of QR codes at **http://tinyurl.com/3cgcx33**.

Quickmark will generate bespoke QR graphics as a BMP, GIF, JPG or PNG (be sure to choose 'QR code' as the code type), for embedding in your own artwork. A phone number, URL, SMS, email address or small text message can all be encoded this way, and a code containing a Google Maps link can be scanned directly onto a mobile, given customers personalised navigation instructions via their mobile browser.

Quickmark QR Reader can decode QR codes on-screen, using it as a 'loupe'

Another resource to browse around is the QR applications specialists BeQrious (**www.beqrious.com**) where some forward-thinking applications of QR codes are explained. You can also build your own codes online (including a small logo at the centre) courtesy of their free online generator.

As I mentioned last month, a competing technology is Near Field Communications (NFC), which enables payments to be made or information to be transmitted wirelessly to some mobile phones. Details are at: **www.nfc-forum.org** and you will undoubtedly see the NFC 'N' logo appearing in the High Street in a few years.

Keep taking the tablets

For surfing the web, emailing or using a webcam, a mobile phone has its limitations, especially for regular use at home, on holiday or in the office. Back in *Net Work* August 2008, I introduced the Asus Eee PC netbook, which heralded a new wave of shrunken laptops capable of running Linux or Windows. Netbooks are still popular because they are very compact, stylish and unintimidating to use, and they boast a conventional-style QWERTY keyboard. Some have a built-in webcam enabling Skype to be used, but they don't have an internal DVD drive.

If a netbook or laptop aren't for you, then the market is awash with new 'tablet' computers. These sleek and seamless devices are entirely self-contained and offer everything needed to work and play online. Tablets invariably use a 7in. or 10in. touchscreen, which hard-bitten QWERTY typists may not find so productive, in which case a Bluetooth keyboard can be used – check availability.

The choice of operating system is a major headache because it controls the choice of applications (apps) that you might want to buy later down the line. Tablet and smartphone reviewers regularly comment about the variable quality of apps, or the lack of compatibility with their chosen OS. Undoubtedly, Apple offers the widest choice of quality apps by far.

Tablet fanatics have been busily devising new apps for their beloved tablets, and I commend to you the beautifully-worked USB Typewriter (**http://www.usbtypewriter.com/**) which hooks an iPad to an old mechanical typewriter, displaying the text onscreen as a sheet of 'paper'. The Ion iCADE adds a retro Atari arcade game front-end to an iPad (**http://www.ionaudio.com/products/details/icade**), and you can buy oscilloscope and test gear apps, music training apps and much more through iTunes, all using the iPad as a display screen.

While Apple offers the trend-setting iPad 2 running Apple's iOS, some familiar PC brands have joined in the fray with Windows 7 and Google Android-based devices. (Android is Google's own OS, using Linux at its core.) For example, the Acer Iconia W500 is a Windows 7 device with a 10.1in. screen costing about £435 ($700); the similar, but cheaper Acer A500 runs Android instead.

Meantime, Research in Motion – best known for the Blackberry smartphone – has launched its new Playbook tablet, which claims a key advantage over the iPad: it runs Flash natively, which allows multimedia and animated websites to be displayed, while Apple users need a mobile browser such as Skyfire to view Flash files. Unfortunately, the Playbook won't currently work with Blackberry's own email service without using some very messy workarounds.

Elsewhere, Motorola's interesting Xoom is a new 10.1in. HD tablet also running Android Honeycomb. The

HP's Touchpad tablet is part of the new wave of tablet devices and it runs under WebOS. A Bluetooth QWERTY keyboard is available

Xoom offers an HDMI port, a Bluetooth QWERTY keyboard and speaker dock as extras. See **www.motorola.com/XOOM** for more details. Samsung offers the Galaxy Tab 10, a 10.1in. Android tablet with Flash support and full HD playback that claims to be the lightest and thinnest large screen tablet available (**www.samsung.com/GalaxyTab**).

As if Windows 7, Apple iOS, Android and Blackberry operating systems aren't enough, HP has arrived on the tablet scene with its WebOS-powered HP Touchpad (**www.palm.com/touchpad**). It was Handspring, you might recall, which used the Palm OS on the Visor Deluxe PDA that I mentioned right at the beginning. Handspring was absorbed into Palm and in turn, HP purchased Palm in 2010. Happily, the Palm OS has evolved into the mobile WebOS used in the Touchpad. The multi-tasking HP Touchpad handles Flash files and the 9.7in. 32GB version should be available by the time you read this. Prices from £399 to £479.

Chrome-plated

In recent weeks, I have been plagued by computer updates slowing down my computer boot-up times, partly thanks to a string of Adobe Reader and Adobe Flash emergency updates. Sometimes it seemed like Windows constantly needed patching too. Imagine a netbook-style device with no application software to worry about at all! The Google OS-based Chromebook (**www.google.co.uk/chromebook**) is designed for always-on web usage, and it uses Wi-Fi (or optionally 3G) to connect directly to the web within eight seconds, it is claimed. The online apps are hosted in the cloud, not on the local hard drive, and they are updated automatically without user intervention.

Chromebook users simply connect to the net to access their email and documents, and they don't have to worry about constantly patching their computer. Any product updates and fixes are downloaded and applied silently. The Chromebook 'dumb terminal' approach may be a good idea in theory, but early reviews are very mixed indeed, and it is unclear how practical the Chromebook will turn out to be, due to its complete dependence on the net. A 12.1in. Chromebook from Samsung has appeared, and Acer will be next to launch its own Chromebook.

Tablets and Chromebooks promise much for the Internet user, but, exciting as they are, one gains a dizzy feeling of a technological *déjà-vu* about the emerging market. The tablet form-factor is now here to stay, but at present, I have a tangible sense of disappointment

The Google Chromebook is an always-on web device that relies on finding an Internet connection

caused by the reportedly lacklustre performance of many tablets, or missing core features that have been criticised by reviewers across the board. There are practical shortcomings in this segment of the market, and a very close scrutiny of spec. sheets and user reviews is necessary before purchasing.

Next month, I'll look at another challenge to tablets – e-readers, wafer-thin displays that let you download e-books from the web and read them on the go. In the meantime, you can email me at: **alan@epemag.demon.co.uk** or write to the editor for possible inclusion in *Readout* at: **editorial@wimborne.co.uk**.

DIRECT BOOK SERVICE

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS SEE THE NEXT TWO ISSUES OF *EPE*

All prices include UK postage

NEW

Electronics Teach-In 3

FREE CD-ROM

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered.

Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 different circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series.

The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages+CD-ROM **Order code ET3** **£8.50**

ROBOTICS

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Then explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages - large format **Order code BP901** **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

198 pages **Order code BP902** **£14.99**

ANDROIDS, ROBOTS AND ANIMATRONS
Second Edition – John Iovine

Build your own working robot or android using both off-the-shelf and workshop constructed materials and devices. Computer control gives these robots and androids two types of artificial intelligence (an expert system and a neural network). A lifelike android hand can be built and programmed to function doing repetitive tasks. A fully animated robot or android can also be built and programmed to perform a wide variety of functions.

The contents include an Overview of State-of-the-Art Robots; Robotic Locomotion; Motors and Power Controllers; All Types of Sensors; Tilt; Bump; Road and Wall Detection; Light; Speech and Sound Recognition; Robotic Intelligence (Expert Type) Using a Single-Board Computer Programmed in BASIC; Robotic Intelligence (Neutral Type) Using Simple Neural Networks (Insect Intelligence); Making a Lifelike Android Hand; A Computer-Controlled Robotic Insect Programmed in BASIC; Telepresence Robots With Actual Arcade and Virtual Reality Applications; A Computer-Controlled Robotic Arm; Animated Robots and Androids; Real-World Robotic Applications.

224 pages **Order code MGH1** **£16.99**

RADIO

BASIC RADIO PRINCIPLES AND TECHNOLOGY
Ian Poole

Radio technology is becoming increasingly important in today's high technology society. There are the traditional uses of radio which include broadcasting and point to point radio as well as the new technologies of satellites and cellular phones. All of these developments mean there is a growing need for radio engineers at all levels.

Assuming a basic knowledge of electronics, this book provides an easy to understand grounding in the topic.

Chapters in the book: Radio Today, Yesterday, and Tomorrow; Radio Waves and Propagation; Capacitors, Inductors, and Filters; Modulation; Receivers; Transmitters; Antenna Systems; Broadcasting; Satellites; Personal Communications; Appendix – Basic Calculations.

263 pages **Order code NE30** **£28.99**

PROJECTS FOR RADIO AMATEURS AND S.W.L.S.
R. A. Penfold

This book describes a number of electronic circuits, most of which are quite simple, which can be used to enhance the performance of most short wave radio systems.

The circuits covered include: An aerial tuning unit; A simple active aerial; An add-on b.f.o. for portable sets; A wavetrap to combat signals on spurious responses; An audio notch filter; A parametric equaliser; C.W. and S.S.B. audio filters; Simple noise limiters; A speech processor; A volume expander.

Other useful circuits include a crystal oscillator, and RTTY/C.W. tone decoder, and a RTTY serial to parallel converter. A full range of interesting and useful circuits for short wave enthusiasts.

92 pages **Order code BP304** **£4.45**

AN INTRODUCTION TO AMATEUR RADIO
I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the last century. This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.

150 pages **Order code BP257** **£5.49**

COMPUTERS AND COMPUTING

ELECTRONICS TEACH-IN 2 CD-ROM

CD-ROM

USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

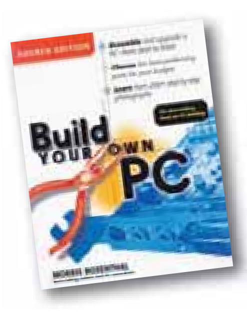
Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers.

An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Microcontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

CD-ROM **Order code ETI2 CD-ROM** **£9.50**



BUILD YOUR OWN PC – Fourth Edition
Morris Rosenthal

More and more people are building their own PCs. They get more value for their money, they create exactly the machine they want, and the work is highly satisfying and actually fun. That is, if they have a unique beginner's guide like this one, which visually demonstrates how to construct a computer from start to finish.

Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. The author goes 'under the hood' and shows step-by-step how to create a Pentium 4 computer or an Athlon 64 or Athlon 64FX, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows XP. The few existing books on this subject, although outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are looking for.

224 pages - large format **Order code MGH2** **£16.99**

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)

A Microchip insider tells all. Focuses on examples and exercises that show how to solve common, real-world design problems quickly. Includes handy checklists to help readers perform the most common programming and debugging tasks. FREE CD-ROM includes source code in C, the Microchip C30 compiler, and MPLAB SIM software, so that readers gain practical, hands-on programming experience.

Until recently, PICs didn't have the speed and memory necessary for use in designs such as video- and audio-enabled devices. All that changed with the introduction of the 16-bit PIC family, the PIC24. This new guide teaches readers everything they need to know about the architecture of these chips, how to program them, how to test them and how to debug them. Lucio's common-sense, practical, hands-on approach starts out with basic functions and guides the reader step-by-step through even the most sophisticated programming scenarios.

Experienced PIC users and newcomers alike will benefit from the text's many thorough examples, which demonstrate how to nimbly side-step common obstacles and take full advantage of all the 16-bit features.

496 pages +CD-ROM **Order code NE45** **£38.00**

NEW FULL COLOUR COMPUTING BOOKS

WINDOWS 7 – TWEAKS, TIPS AND TRICKS
Andrew Edney

This book will guide you through many of the exciting new features of Windows 7. Microsoft's latest and greatest operating system. It will provide you with useful hints, tips and warnings about possible difficulties and pitfalls. This book should enable you to get much more out of Windows 7 and, hopefully, discover a few things that you may not have realised were there.

Among the topics covered are: A brief overview of the various versions of Windows 7. How to install and use Upgrade Advisor, which checks to see if your computer meets the minimum requirements to run Windows 7 and that your software and drivers are supported by Windows 7. How to use Windows Easy Transfer to migrate your data and settings from your Vista or XP machine to your new Windows 7 computer. Exploring Windows 7 so that you will become familiar with many of its new features and then see how they contrast with those of earlier versions of Windows. How to connect to a network and create and use Home Groups to easily share your pictures, videos, documents, etc.,with the minimum of hassle. Why Windows Live Essentials is so useful and how to download and install it. A brief introduction to Windows Media Center. The use of Action Center, which reports security and maintenance incidents. Windows Memory Diagnostic to detect the fairly common problem of faulty memory and Troubleshooting tools.

120 pages **Order code BP708** **£8.49**

HOW TO BUILD A COMPUTER MADE EASY
R.A. Penfold

Building your own computer is a much easier than most people realise and can probably be undertaken by anyone who is reasonably practical. However, some knowledge and experience of using a PC would be beneficial. This book will guide you through the entire process. It is written in a simple and straightforward way with the explanations clearly illustrated with numerous colour photographs.

The book is divided into three sections: *Overview and preparation* – Covers understanding the fundamentals and choosing the most suitable component parts for your computer, together with a review of the basic assembly. *Assembly* – Explains in detail how to fit the component parts into their correct positions in the computer's casing, then how to connect these parts together by plugging the cables into the appropriate sockets. No soldering should be required and the only tools that you are likely to need are screwdrivers, small spanners and a pair of pliers.

BIOS and operating system – This final section details the setting up of the BIOS and the installation of the Windows operating system, which should then enable all the parts of your computer to work together correctly. You will then be ready to install your files and any application software you may require.

The great advantage of building your own computer is that you can 'tailor' it exactly to your own requirements. Also, you will learn a tremendous amount about the structure and internal workings of a PC, which will prove to be invaluable should problems ever arise.

120 pages **Order code BP707** **£8.49**

AN INTRDUCTION TO eBAY FOR THE OLDER GENERATION
Cherry Nixon

eBay is an online auction site that enables you to buy and sell practically anything from the comfort of your own home. eBay offers easy access to the global market at an amazingly low cost and will enable you to turn your clutter into cash.

This book is an introduction to eBay.co.uk and has been specifically written for the over 50s who have little knowledge of computing. The book will, of course, also apply equally to all other age groups. The book contains ideas for getting organised for long term safe and successful trading. You will learn how to search out and buy every conceivable type of thing.The book also shows you how to create auctions and add perfect pictures. There is advice on how to avoid the pitfalls that can befall the inexperienced.

Cherry Nixon is probably the most experienced teacher of eBay trading in the UK and from her vast experience has developed a particular understanding of the issues and difficulties normally encountered by individuals.

So, if you are new to computers and the internet and think of a mouse as a rodent, then this is the book for you!

120 pages **Order code BP709** **£8.49**

GETTING STARTED IN COMPUTING FOR THE OLDER GENERATION
Jim Gatenby

You can learn to use a computer at any age and this book will help you acheive this. It has been especially written for the over 50s, using plain English and avoiding technical jargon wherever possible. It is lavishly illustrated in full colour.

Among the many practical and useful subjects that are covered in this book are: Choosing the best computing system for your needs. Understanding the main hardware components of your computer. Getting your computer up and runnning in your home. Setting up peripheral devices like printers and routers. Connecting to the internet using wireless broadband in a home with one or more computers. Getting familiar with Windows Vista and XP the software used for operating and maintaining your computer. Learning about Windows built-in programs such as Windows Media Player, Paint and Photo Gallery.

Plus, using the Ease of Access Center to help if you have impaired eyesight, hearing or dexterity problems. Installing and using essential software such as Microsoft Office suite. Searching for the latest information on virtually any subject. Keeping in touch with friends and family using e-mail. Keeping your computer running efficiently and your valuable data files protected against malicious attack.

This book will help you to gain the basic knowledge needed to get the most out of your computer and, if you so wish, give you the confidence to even join a local computer class.

120 pages **Order code BP704** **£8.49**

THEORY AND REFERENCE

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS
Third Edition
Mike Tooley

A comprehensive reference text and practical electronics handbook in one volume – at an affordable price!

New chapter on PIC microcontrollers – the most popular chip family for use in project work by hobbyists and in colleges and universities.

New companion website: spreadsheet design tools to simplify circuit calculations; circuit models and templates to enable virtual simulation; a bank of on-line questions for lecturers to set as assignments, and on-line self-test multiple choice questions for each chapter with automatic marking, to enable students to continually monitor their progress and understanding.

The book's content is matched to the latest pre-degree level courses, making this an invaluable reference for all study levels, and its broad coverage is combined with practical case studies, based in real-world engineering contexts throughout the text.

The unique combination of a comprehensive reference text, incorporating a primary focus on practical applications, ensures this text will prove a vital guide for students and also for industry-based engineers, who are either new to the field of electronics, or who wish to refresh their knowledge.

400 pages **Order code NE43** **£25.99**

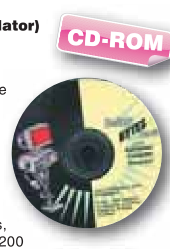
BEBOP TO THE BOOLEAN BOOGIE
Third Edition
Clive (Max) Maxfield

This book gives the 'big picture' of digital electronics. This indepth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

Contents: Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

500 pages **Order code BEB1** **£32.99**

BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield and Alvin Brown



This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. if you're the slightest bit interested in the inner workings of computers, then don't dare to miss this!

Over 800 pages in Adobe Acrobat format

CD-ROM **Order code BEB2 CD-ROM** **£21.95**

FUNDAMENTAL ELECTRICAL AND ELECTRONIC PRINCIPLES
Third Edition
C. R. Robertson

Covers the essential principles that form the foundations for electrical and electronic engineering courses. The coverage of this new edition has been carefully brought in line with the core unit 'Electrical and Electronic Principles' of the 2007 BTEC National Engineering specification. This qualification from Edexcel attracts more than 10,000 students per year.

The book explains all theory in detail and backs it up with numerous worked examples. Students can test their understanding with end of chapter assignment questions for which answers are provided. In this new edition, the layout has been improved and colour has been added. A free companion website with additional worked examples and chapters is also available.

368 pages **Order code NE47** **£21.99**

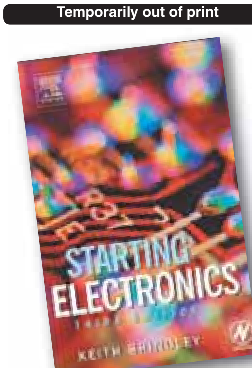
STARTING ELECTRONICS
Third Edition
Keith brindley

A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.

A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.

Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

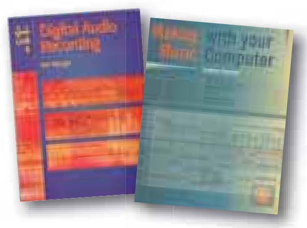
Temporarily out of print



MUSIC, AUDIO AND VIDEO

MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett
Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.
You'll learn about recording techniques, software and effects, mixing, mastering and CD production.
Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

92 pages **Order code PC120** £10.95



QUICK GUIDE TO MP3 AND DIGITAL MUSIC
Ian Waugh
MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?
All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:
How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.
Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

60 pages **Order code PC119** £7.45

DIGITAL AUDIO RECORDING
Ian Waugh
All modern music recordings use digital audio technology. Now everyone with a computer can produce CD-quality recordings and this book shows you how.
Written in a clear and straightforward style, it explains what digital audio recording is, how to use it, the equipment you need, what sort of software is available, and how to achieve professional results.

It explains:
- What computer system you need
- Sound and digital audio essentials
- What to look for in a sound card
- What effects to use
- The art of mixing
- Recording techniques
- How to use virtual instruments
- How to edit audio and create loops

Computer-based recording is the future of music and this book shows how you can join the revolution now.

60 pages **Order code PC121** £7.95

RADIO BYGONES

We also carry a selection of books aimed at readers of *EPE*'s sister magazine on vintage radio *Radio Bygones*. These books include, the four volumes of our own *Wireless For the Warrior* by Louis Meulstee. These are a technical history of radio communication equipment in the British Army and clandestine equipment from pre-war through to the 1960s.
For details see the UK shop on our web site at www.epemag.com or contact us for a list of *Radio Bygones* books.

PROJECT BUILDING AND TESTING

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:
Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.
In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** £5.99

BUILDING VALVE AMPLIFIERS
Morgan Jones
The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.
A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.
Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** £29.00

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** £5.45

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.
In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

102 pages **Order code BP239** £5.49

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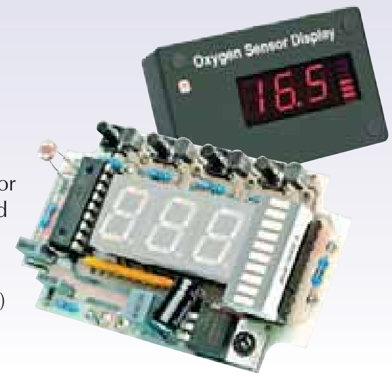
Next Month



Wideband Air-Fuel Mixture Display

Running efficiently and not wasting fuel makes great sense. This Wideband Oxygen Sensor Display can show your car's air-fuel ratio as you drive. It's designed to monitor a wideband oxygen sensor and its associated wideband controller, but could be used to monitor a narrowband oxygen sensor instead.

Open-USB-IO: a universal I/O solution

This powerful digital project lets you drive a host of digital and analogue I/O (input/outputs) via the USB interface on your laptop or desktop computer. Based on an Atmel Atmega32 microprocessor and not much else, it works on Windows, Linux and Macs.

A high-quality stereo DAC for superb sound from your DVD player – Part 2

Last month, we introduced our new high-quality stereo DAC and described the circuit. This month, we show you how to build the various modules and make the header cables.

Twin Engine SpeedMatch Indicator

Avoid unnecessary noise and vibration in twin-engine boats by using this Twin Engine SpeedMatch Indicator. It uses a meter that is centred when both motors are running at the same speed. When the motors are not matched in revs, the meter shows which motor is running faster and by how much.

OCTOBER '11 ISSUE ON SALE 8 SEPTEMBER

Content may be subject to change

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